Approved 10/18/05
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TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, California 93110-2847
Telephone (805) 681-3100
Fax (805) 681-3108
e-mail ttsba@tetratech com

09 September 2005

Ms Kathleen Gerber
Department of the Air Force
AFCEE/ICS
806 13th Street, Suite 116
Vandenberg AFB, CA 93437

Subject: Final Engineering Evaluation/Cost Analysis (EE/CA) for Site 13 Cluster (C), Vandenberg Air Force Base (AFB), California

Reference: Contract No F41624-03-D-8617, Task Order 0046, CDRL A005

Dear Ms. Gerber:

On behalf of the Air Force, Tetra Tech, Inc is submitting the replacement cover, spine, and figures for the Final EE/CA for Site 13C. Copies are also being provided to the Department of Toxic Substances Control (DTSC) and the Regional Water Quality Control Board (RWQCB). Please replace the existing Draft Final EE/CA for Site 13C cover, spine, and figures with the replacement cover, spine, and figures enclosed within.

If you have any questions or concerns regarding this matter, please feel free to contact David Springer by telephone at (805) 681-3100, extension 113 or by email at david.springer@tetratech.com

Sincerely,

TETRA TECH, INC.

REGISTERED GEOLOGIST
DAVID S. SPRINGER
NO. 6962
STATE OF CALIFORNIA

David Springer, P.G. No. 6962
Principal Hydrogeologist

cc with enclosure:
- MacElligott, M , VAFB-IRP
- McNamara, K., Tt-SBA
- Nathe, C., VAFB-IRP
- Parsons, F., Tt-SBA
- Stone, L /Kolb C., RWQCB
- Than, Q /Mahmoud, T., DTSC
- 99046 File

Ms Kathleen Gerber
09 September 2005
C155-1706

cc w/out enclosure:

Freedom, K., It-SBA
Kephart, B., VAFB-IRP
MacLelland, R., VAFB-IRP
Petersen, B., It-SBA
Peterson, M, It-SBA
Correspondence File

EXECUTIVE SUMMARY

Environmental investigations conducted at Installation Restoration Program (IRP) Site 13 Cluster (13C) indicate that previous missile launch activities at the Advanced Ballistic Re-Entry Systems-A (ABRES-A) Launch Complex, Vandenberg Air Force Base (AFB) have impacted groundwater quality at the site. Site 13C comprises Sites 13, 14, and 28, which are located adjacent to one another in the Burton Mesa physiographic region in the northern part of Vandenberg AFB. Due to their proximity, shared environmental characteristics, linked operational histories, and contaminant migration pathways, the sites are clustered and will be referred to in this document as Site 13C. Site 13C includes the ABRES-A Launch Complex, a portion of ABRES-A Canyon to the south and west of the launch complex, ABRES-A Lake, and Missile Silo 395-B

Previous investigations at Site 13C document the presence of volatile organic compounds (VOCs) in groundwater at concentrations in excess of California drinking water standards The groundwater has been contaminated with trichloroethene (TCE), which, through natural attenuation, has been reduced to dichloroethene (DCE) and vinyl chloride as it migrates along the paleochannel. Computer modeling has indicated that if left untreated, the groundwater plume would increase in size and migrate beyond the monitoring network. Due to requirements of the State Water Resources Control Board, groundwater at the site has a designated future beneficial use as drinking water. This engineering evaluation/cost analysis (EE/CA) evaluates and compares alternatives for an IRA to control plume migration and reduce VOC concentrations in the paleochannel at Site 13C such that concentrations at the downgradient sentry wells (14-MW-5 and 14-MW-8) do not exceed Applicable or Relevant and Appropriate Requirements. The final remedy for the source area(s) at Site 13C will be addressed in the Feasibility Study for this Site

The EE/CA is part of a non–time-critical removal action under the Comprehensive Environmental Response, Compensation and Liability Act and is being conducted in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) subpart (E): Hazardous Substance Response.

Initially, five alternatives were identified and considered: (1) No Action, (2) Monitored Natural Attenuation, (3) *In-Situ* Bioremediation, (4) *In-Situ* Chemical Oxidation, and (5) *Ex-Situ* Groundwater Treatment From this initial screening, in-situ biological remediation ranked the highest. Five different process variations relying on strategies to enhance anaerobic and/or aerobic biodegradation using in-situ methods underwent a more detailed screening. These process variables included:

- Hydrogen Release Compound, Extended Release Formula (HRC-X) injection at both the Watt Road and the downgradient paleochannel area;

- HRC-X injection at the Watt Road area with Oxygen Release Compound (ORC) injection at the downgradient paleochannel area;

- Hydrogen gas diffusion at the Watt Road area with oxygen diffusion at the downgradient paleochannel area using *in-situ* submerged oxygen curtain (iSOC) hollow-fiber membrane units;

- Soybean oil injection at both the Watt Road and the downgradient paleochannel areas; and

- Soybean oil injection at Watt Road with oxygen diffusion at the downgradient paleochannel using iSOC.

The comparative analysis of remedial alternatives presented in this EE/CA is based on the nine NCP comparative criteria Based on these analyses, the Air Force recommends injection of soybean oil into a series of injection wells oriented perpendicular to the groundwater plume at the Watt Road area and oxygen diffusion via iSOC units placed into a well array at the downgradient paleochannel area. The dual-technology soybean oil injection and oxygen diffusion alternative provides one the lowest present-value costs of the active alternatives, is well suited to the aquifer conditions at each treatment location, and best meets the removal action objectives and the NCP evaluation criteria.

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1.0 INTRODUCTION

Environmental investigations conducted at Installation Restoration Program (IRP) Site 13 Cluster (13C) indicate that previous missile launch activities at the Advanced Ballistic Re-Entry Systems-A (ABRES-A) Launch Complex, Vandenberg Air Force Base (AFB), have impacted groundwater quality at the site. Site 13C comprises Sites 13, 14, and 28, which are located adjacent to one another in the Burton Mesa physiographic region in the northern part of Vandenberg AFB (Figures 1-1 and 1-2). Site 13 includes the ABRES-A Launch Complex, and a portion of ABRES-A Canyon to the south and west of the launch complex. The site is bordered on the west by Sites 14 (ABRES-A Lake and paleochannel) and 28 (Missile Silo 395-B). Due to their proximity, shared environmental characteristics, linked operational histories, and contaminant migration pathways, the three sites are clustered and will be referred to in this document as Site 13C.

Previous investigations at Site 13C indicated that volatile organic compounds (VOCs) are present in groundwater at concentrations in excess of California drinking water standards. The groundwater has been contaminated with trichloroethene (TCE), which, through natural attenuation, has been reduced to dichloroethene (DCE) and vinyl chloride as it migrates along the paleochannel. Computer modeling has indicated that if left untreated, the groundwater plume would increase in size and migrate beyond the monitoring network (Tetra Tech, Inc. [Tetra Tech] 2004a). This engineering evaluation/cost analysis (EE/CA) evaluates and compares alternatives for an interim removal action (IRA) to control plume migration and reduce VOC concentrations in the paleochannel at Site 13C such that concentrations at the downgradient sentry wells (14-MW-5 and 14-MW-8) do not exceed Applicable or Relevant and Appropriate Requirements (ARARs). The final remedy for the source area(s) at Site 13C will be addressed during the Feasibility Study (FS)

The EE/CA is part of a non–time-critical removal action under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and is being conducted in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) subpart (E): Hazardous Substance Response. The comparative analysis of remedial alternatives presented in this EE/CA is based on technical feasibility, reasonable cost, institutional considerations, time constraints, and human health and environmental impacts

1.1 PURPOSE AND OBJECTIVES OF THE EE/CA

The purpose of an EE/CA is to identify objectives of a non-time critical removal action, and evaluate and select a feasible technology for the removal action (U.S. Environmental Protection Agency [U.S. EPA] 1993). Specific objectives of the EE/CA are to:

- Demonstrate that regulatory requirements for non–time-critical removal actions are met;
- Provide a methodology for evaluating and selecting alternative technologies;
- Provide information on remedial technologies, including a cost analysis and completion schedule; and
- Provide documentation of the decision-making process for removal actions for inclusion in the administrative record.

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2.0 SITE CHARACTERIZATION

2.1 SITE DESCRIPTION

Site 13

The ABRES-A Launch Complex at Site 13 consists of a control center and three launch pads (Buildings 1788, 1790, and 1797), as shown on Figure 1-2 A single 15,000-gallon Rocket Propellant-1 (RP-1) fuel underground storage tank (UST) was installed at each launch pad. The RP-1 USTs were previously removed from Pads 1 and 2; the UST at Pad 3 was abandoned in place Chlorinated solvents, primarily TCE, were used on-site for degreasing missile engines and for cleaning parts. A TCE storage tank was located within the launch service building at each pad.

Launch operation deluge channels extend from each of the three launch pads toward ABRES-A Canyon. Before the use of solvents at Vandenberg AFB was regulated, TCE and possibly other solvents were released to the deluge water channels, which may have caused releases to other areas on-site. Deluge Channel A originates at Pad 1. The first section of Channel A is 50 feet wide by 450 feet long and lined with concrete. The second section of Channel A is 50 feet long and consists of concrete riprap. A 700-foot-long, unlined (earthen) channel leads from the riprap to a natural tributary of ABRES-A Canyon. Deluge Channel B originates at Pad 2. The first section of Channel B is 50 feet wide by 120 feet long, very steeply inclined, and lined with concrete. The second section of Channel B is in ABRES-A Canyon, is 50 feet long, and consists of concrete riprap Deluge Channel C originates at Pad 3, is 50 feet wide by 250 feet long, is lined with concrete, and ends with 50 feet of concrete riprap. The remaining 700 feet of Channel C are unlined and discharge into a small earthen retention basin at the edge of ABRES-A Canyon (Figure 1-2).

Site 14

Site 14 includes ABRES-A Lake, the western portion of ABRES-A Canyon and surrounding bluffs, the discharge point of an earthen drainage channel from Site 28 (Missile Silo 395-B), and the neutralization lagoon located on the north bluff of the canyon (Figure 1-2). The lake was the receptor of surface water drainage and previous waste discharge from Sites 13 and 28.

Site 28

Site 28 comprises Missile Silo 395-B (Building 1799) and is located at the west end of Watt Road (Figure 1-2). Formerly a Titan II missile launch facility, the site has been unoccupied since the early 1970s The Titan II missile used the hypergolic fuels Aerozine-50 and nitrogen tetroxide. When Missile Silo 395-B was operational, 16 Titan missiles were launched The upper and lower concrete-lined hardstands for loading Aerozine-50 and nitrogen tetroxide are adjacent to the silo Two Aerozine-50 hardstands are on the eastern side of the silo and two nitrogen tetroxide hardstands are on the northwest side of the silo. According to Vandenberg AFB engineering drawings, each recessed, concrete-lined lower hardstand is approximately 20 feet wide by 150 feet long, with a central rectangular depression. A 60,000-gallon Aerozine-50 UST used for fuel downloading operations was located next to the lower Aerozine-50 hardstand but has been removed. Since the UST removal, up to 2 feet of soil/sediment has accumulated on the Aerozine-50 lower hardstand. Most of the accumulated soil/sediment is likely left from excavation activities during the tank removal Since site abandonment, both lower hardstands seasonally accumulate rainwater.

A lined retention basin and an unlined oxidation basin are found on the southern portion of the site. During launch operations, an unlined drainage channel discharged runoff south of the site into ABRES-A Canyon. This drainage channel is no longer maintained and currently does not discharge site runoff into ABRES-A Canyon.

2.1.1 Geology

The ABRES-A Canyon comprises a channel in Miocene Monterey Formation bedrock that is partially filled with recent alluvial deposits and dune sand. At the western end, ABRES-A Canyon terminates at the leading edge of eastward migrating recent and active dune sands. The dune sands form the natural dam that created ABRES-A Lake. Typically, this dune sand consists of fine-grained, well-sorted sand and silty sand with high permeability. The shale bedrock beneath the recent alluvial deposits is locally weathered and appears to impede groundwater migration and transport of aqueous contaminants through bedrock (Tetra Tech 2004a).

In October 1999, a seismic reflection geophysical survey was conducted in the dune area downgradient and west of ABRES-A Lake to map the Monterey Shale/dune sand contact and trace the orientation of the buried paleochannel extension of ABRES-A Canyon. Based on drilling, geological mapping, and the seismic survey, the paleochannel is shown in plan view on Figure 2-1 and in cross-section along its longitudinal axis on Figure 2-2. Soil thickness along the axis of the paleochannel ranges from approximately 110 to 150 feet.

2.1.2 Hydrology

Site 13 Cluster is located on the drainage divide of two major groundwater basins: the Santa Ynez River Basin to the south and the San Antonio Creek Basin to the north. There are no potable water wells within five miles of the site. The nearest potable water wells (designated San Antonio Wells No. 4, 5, 6, and 7A) are located approximately 7.5 miles east and upgradient of the site in Barka Slough of San Antonio Creek. There is no significant groundwater (i.e., aquifer) below the portion of the site cluster that resides on Burton Mesa, namely the mesa portion of Sites 13 and 28. Perennial surface water at the Site 13 Cluster is limited to ABRES-A Lake. ABRES-A Lake has a drainage area of approximately 1,375 acres, which extends as far east as the main cantonment area. The deepest part of the lake has been observed to range from a minimum of 8 feet during dry periods to over 45 feet after heavy winter rains. Hydrological investigations performed during the Remedial Investigation (RI) indicate there is a hydraulic connection between the lake and the subsurface canyon groundwater aquifer, and, as a result, a significant portion of the surface water in ABRES-A Lake is fed by groundwater (Tetra Tech 2004a).

The paleochannel, located downgradient of ABRES-A Lake, conveys groundwater from the lake in a northwest direction with an average hydraulic gradient of 0.001 feet per foot. A groundwater contour map (Figure 2-3) shows the apparent direction of groundwater flow. Because the paleochannel would potentially provide a migration pathway for contaminants in groundwater, monitoring wells were placed along its axis. Monitoring wells 13-MW-1, 13-MW-2, 13-MW-3, 13-MW-6, 13-MW-7, 14-MW-1, and 14-MW-2 have been periodically submerged by the lake after times of significant rainfall.

Top of groundwater was encountered in ABRES-A Canyon and the paleochannel downgradient of ABRES-A Lake at depths ranging from the ground surface (including ABRES-A Lake) to approximately 84 feet below ground surface (bgs). The saturated thickness of the aquifer in ABRES-A Canyon, located upgradient of and beneath ABRES-A Lake, ranges from approximately 0 feet near the edge of the canyon wall to approximately 73 feet on the western side of the lake near monitoring well 14-MW-2.

Downgradient of ABRES-A Lake along the paleochannel axis, the saturated zone ranges from approximately 40 to 87 feet in thickness.

During the RI, slug tests were performed on ABRES-A Canyon monitoring wells to measure aquifer hydraulic conductivity (K) and transmissivity near the wells. Results indicated K values ranging from 1.7 feet per day (feet/day) upgradient of the lake to 49.6 feet/day downgradient from the lake.

2.1.3 Biotic Setting

Sites 13, 14, and 28 are considered as a group for the baseline Ecological Risk Assessment (ERA) because they are adjacent, have similar hydrogeologic features, and support similar habitats (Tetra Tech 2004a). A 10-foot cyclone security fence separates and surrounds Sites 13 and 28. Both Site 28 and the bluff areas at Site 13 are situated in coastal sage scrub habitat, while ABRES-A Canyon consists of riparian and freshwater emergent/aquatic habitats. Small vernal pools are located in the neutralization lagoon at Site 14 and in the nitrogen tetroxide and lower Aerozine-50 hardstands at Site 28.

Coastal sage scrub vegetation is dominated by drought-resistant, deciduous, and shallow-rooted shrubs, normally less than 3 feet tall, with a herbaceous underlayer of annual forbs and grasses (Mayer and Laudenslayer 1988; The Nature Conservancy 1991). Coastal sage scrub is a characteristic feature of drier sites and is typical of areas with an average annual rainfall of less than 12 inches. The coastal sage scrub vegetation is a relatively stable vegetation type that can re-establish itself after disturbances such as fires (Mayer and Laudenslayer 1988). The dominant plants include coastal sagebrush, coyote brush, coast goldenbush, and cass (Coulombe and Cooper 1976; Schmalzer *et al.* 1988). Five special-status plants occur in the coastal sage scrub community on Vandenberg AFB. The beach layia (*Layia carnosa*) is a federal and California endangered plant species expected in coastal sage scrub habitat at Vandenberg AFB. Black-flowered figwort (*Scrophularia atrata*), crisp monardella (*Monardella crispa*), San Luis Obispo monardella (*Monardella frutescens*), and aphanisma (*Aphanisma blitoides*) are among the federal plant species of concern expected in coastal sage scrub habitat at Vandenberg AFB. These five special-status plants and the Morro Bay blue butterfly (*Icaricia icarioides moroensis*), a federal candidate species, are found only in coastal sage scrub habitat on Vandenberg AFB, and could be found in coastal sage scrub habitat at the site cluster. Bush lupine (*Lupinus* sp.) is an ecologically important plant species in that it is the host plant for the candidate Morro Bay blue butterfly. Typical coastal scrub animals likely to visit ABRES-A Lake include birds and large mammals.

Riparian habitat is dominated by plant species such as willows and cottonwoods, which require abundant soil moisture. Riparian habitat is found along streams and other moist areas where water is available most of the year. The riparian habitat is characterized by considerable structural heterogeneity including a tree canopy, a dense shrub understory, and a herbaceous plant layer. Because of their structural complexity, riparian habitats typically support a diverse animal assemblage. Species from the riparian habitat in ABRES-A Canyon are likely to frequent the adjacent ABRES-A Lake

Freshwater emergent/aquatic habitats at Vandenberg AFB are generally shallow and fringed with wetland plants, such as sedges and bulrushes. ABRES-A Lake is not connected by surface water to any other water body and fish have not been observed during surface water and sediment sampling and biological reconnaissance visits. ABRES-A Lake is not expected to support a fish population, particularly as water levels have declined steadily in recent years. However, it is likely to support aquatic insects and amphibians. The fringes of the lake are dominated by freshwater marsh vegetation. Waterfowl (e.g., mallards, coots), rails, and herons are likely to use this habitat for feeding and nesting activities. No formal protocol surveys of the California red-legged frog have been conducted at Site 13C. However, California red-legged frogs (both adult and tadpole) have been noted in two of three areas of standing water and sediment recently discovered by Vandenberg AFB personnel. Tetra Tech has proposed to characterize concentrations of site contaminants of potential concern in surface water and sediment in each of these standing water areas (Tetra Tech 2004b). The results will be used to evaluate the potential impacts to the California red-legged frogs and to define the source of these bodies of standing water. Once the source and nature of these standing bodies of water have been ascertained, a determination of whether this aquatic habitat is suitable for the California red-legged frog will be made.

As a result of the juxtaposition of these three primary habitats within this site cluster, numerous plant and animal species are likely to be present. Many of these species may use more than one habitat, while a few may be limited to only a particular habitat type. Five special-status plants and the Morro Bay blue butterfly may potentially be found only in the coastal sage scrub habitat in this site cluster. In addition, several widely distributed special-status animals, including the federally threatened and state endangered bald eagle, the state endangered peregrine falcon, and three California species of special concern (yellow warbler, merlin, and Townsend's western big-eared bat), may be found within this site cluster. The western snowy plover (*Charadrius alexandrinus*) is a federally threatened species and a California Species of Special Concern that is known to nest in the dune coastal habitat approximately 1,000 feet downgradient of Site 14. During the nesting season from 1 March to 30 September, coastal access is restricted (Tetra Tech 2004a).

2.2 BACKGROUND

2.2.1 Previous Investigations

Reynolds, Smith and Hill, Inc. (Reynolds), Battelle Corporation (Battelle), and Science Applications International Corporation (SAIC) performed environmental investigations at the site cluster and identified potential contaminant release sites and potential contaminants of concern. SAIC drilled, installed, and sampled monitoring wells 13-MW-1 and 14-MW-1. During the SAIC investigation, TCE was detected at a concentration of 1,200 micrograms per liter (µg/L) in the groundwater sample from well 13-MW-1, and no VOCs were detected in well 14-MW-1. In 1993 Jacobs Engineering Group (JEG) prepared a Phase I RI Work Plan for the sites. The conceptual site model (CSM) presented in the work plan attributed the primary source of contaminant release to the large volume of deluge water released during launches from Site 13, discharge and drainage from Site 28, and discharge from the neutralization lagoon located on the bluff north of ABRES-A Lake. Potential site contaminants identified in discharged waters included metals, solvents, neutralized fuels, and potential leakage from fuel storage tanks and abandoned drums. Possible migration pathways were identified as air, surface water, and groundwater. For more information regarding these site investigations, please refer to the Draft RI Report for Site 13C (Tetra Tech 2004a). Results for organic compounds detected in site groundwater from the Tetra Tech RI and the ongoing Basewide Groundwater Monitoring Program (BGMP) are summarized on Table 2-1

Tetra Tech reviewed the RI work plan prepared by JEG and performed Phase I and Phase II of the RI at Site 13C. During the Phase I of the RI, four monitoring wells (13-MW-2 through 13-MW-5) were installed at Site 13 and one monitoring well (14-MW-2) was installed at Site 14. Monitoring wells 13-MW-4 and 13-MW-5, located on Burton Mesa above ABRES-A Canyon, remained dry during the RI and therefore could not be sampled. During the Phase II of the RI, three monitoring wells (13-MW-6 through 13-MW-8) were installed at Site 13 and five monitoring wells (14-MW-3 through 14-MW-8) were installed at Site 14. Wells 14-MW-9 and 14-MW-10 were installed in fall 2003 to support the groundwater treatability study as described in Section 2.2.4.

Table 2-1
Site 13 Cluster Groundwater Contaminant Summary

Contaminant of Concern	Number of Samples	Range of Detection (µg/L)	Location of Maximum	Number of Samples Exceeding MCLs
TCE	160	ND, 1,300	13-MW-1	19
cis-1,2-DCE	160	ND, 1,580	13-MW-1	64
trans-1,2-DCE	160	ND, 21	14-MW-3	9
1,1-DCE	160	ND, 6.71	13-MW-1	1
Vinyl chloride	160	ND, 51.9	13-MW-1	46

Notes: Data from 1994 through summer 2003
µg/L – micrograms per liter
ND – Non detectable concentration
MCL– California Maximum Contaminant Level.

The results of 15 rounds of groundwater sampling and analysis from the groundwater monitoring wells located in ABRES-A Canyon and the paleochannel are presented below. Samples were collected during winter 1994; fall 1997; spring and summer 2000; winter, spring, summer, and fall 2001; winter, spring, summer and fall 2002; and winter, spring, and summer 2003. Quarterly groundwater monitoring is continuing at the Site 13 Cluster under the BGMP.

No total petroleum hydrocarbons or semivolatile organic compounds have been detected in samples from Site 13 Cluster monitoring wells. A hydrazine concentration of 2.2 µg/L was detected in one Phase I groundwater sample from monitoring well 14-MW-1 but was not detected in subsequent groundwater sampling events. Metals detected in groundwater are not part of the scope of the groundwater IRA, as this work plan addresses chlorinated solvents detected in groundwater downgradient of ABRES-A Lake. Results for VOCs are presented in greater detail below.

2.2.2 VOCs in Conventional Groundwater Samples

Acetone, benzene, bromoform, 2-butanone, carbon disulfide, chlorobenzene, chloroform, dibromochloromethane, 1,1-DCE, *cis*-1,2-DCE, *trans*-1,2-DCE, methylene chloride, TCE, toluene, and vinyl chloride were detected in conventional groundwater samples (i.e., samples collected from a properly installed, developed, and purged monitoring well) from wells located in ABRES-A Canyon and the paleochannel downgradient of ABRES-A Lake. Of these compounds, the only frequently detected VOCs were TCE and its associated degradation by-products *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride; these are addressed individually below. Historical groundwater results for these key VOCs are shown on Figure 2-4

During the Phase I investigation, TCE was detected at concentrations of 69.5 and 548 µg/L in groundwater samples from wells 13-MW-1 and 13-MW-2, respectively. Well 13-MW-1 is located near the bottom of deluge Channel A and well 13-MW-2 is located near the bottom of deluge Channel B in ABRES-A Canyon. Since the Phase I investigation, TCE has been detected in groundwater from wells 13-MW-1, 13-MW-2, 13-MW-3, 13-MW-6, 13-MW-7, and 14-MW-7. Monitoring wells 13-MW-1 and 13-MW-7 are located next to each other in ABRES-A Canyon near the bottom of ABRES-A Launch Complex Deluge Channel A. The highest TCE concentration detected at the site (1,300 µg/L) was in summer 2002 from well 13-MW-1, screened from the top to the middle of the shallow saturated zone. Concentrations of TCE as high as 1,000 µg/L have been detected in samples from well 13-MW-7, screened near the bottom of the saturated zone.

The compound *cis*-1,2-DCE has been detected in samples from wells 13-MW-1, 13-MW-2, 13-MW-6, 13-MW-7, 14-MW-1, 14-MW-2, 14-MW-3, 14-MW-4, 14-MW-6, and 14-MW-7 at concentrations ranging from 0.36 µg/L to 1,580 µg/L. The highest *cis*-1,2-DCE concentration was detected in the spring 2003 sample from well 13-MW-1, located near the bottom of ABRES-A Launch Complex Deluge Channel A and near the southeastern edge of ABRES-A Lake. Concentrations of *cis*-1,2-DCE greater than 250 µg/L have been detected in groundwater samples from wells 13-MW-1, 13-MW-7, 14-MW-2, and 14-MW-3, located in the western portion of ABRES-A Canyon.

The compound *trans*-1,2-DCE has been detected in samples from wells 13-MW-1, 13-MW-2, 13-MW-7, 14-MW-1, 14-MW-2, 14-MW-3, 14-MW-4, 14-MW-6, and 14-MW-7 at concentrations ranging from 0.15 to 21 µg/L. The highest *trans*-1,2-DCE concentrations have historically been detected in groundwater samples from well 14-MW-3.

The compound 1,1-DCE has been detected in samples from wells 13-MW-1, 13-MW-7, 14-MW-2, and 14-MW-3 at concentrations ranging from 0.48 µg/L to 6.71 µg/L. The highest concentrations were detected in the spring 2003 sample from well 13-MW-1, located near the bottom of ABRES-A Launch Complex Deluge Channel A and near the southeastern edge of ABRES-A Lake.

Vinyl chloride is a common product of DCE degradation and has been detected in groundwater samples from wells 13-MW-1, 13-MW-7, 14-MW-1, 14-MW-2, 14-MW-3, 14-MW-4, and 14-MW-7 at concentrations ranging from 0.29 to 51.9 µg/L. The highest vinyl chloride concentration was detected in the spring 2003 sample from well 13-MW-1. Since the Phase I investigation, the highest average vinyl chloride concentrations in conventional groundwater samples have historically been detected in samples from well 14-MW-3, and have ranged from 11 to 38.3 µg/L (Tetra Tech 2003b).

2.2.3 Discrete-Depth Groundwater Sample Results

Analytical results from discrete-depth groundwater samples are regarded as screening level data only, and have not been used to estimate exposures in the risk assessments. However the VOC data obtained from the discrete depth samples are relevant to characterizing the chlorinated solvent plume at the Site 13 Cluster.

Discrete-depth groundwater samples were collected from the open boreholes for wells 13-MW-6, 13-MW-7, 14-B-3, 14-MW-3, and 14-MW-7 and at the sentry well, 14-MW-8. The only frequently detected VOCs were chlorinated solvents such as TCE and its associated degradation by-products DCE and vinyl chloride. A summary of VOCs detected in discrete-depth groundwater samples is provided in Table 2-2.

The compound *cis*-1,2-DCE was detected at locations 13-MW-6, 13-MW-7, 14-B-3, and 14-MW-3 at concentrations ranging from 14 to 220 µg/L. The highest *cis*-1,2-DCE concentration was detected near the bottom of the saturated zone from well 13-MW-7

Concentrations of 1,1-DCE ranging from 0.65 to 1.4 µg/L were detected in discrete-depth groundwater samples collected from the top and middle of the saturated zone at the borehole for well 13-MW-7 but were not detected in other discrete-depth groundwater samples.

The compound *trans*-1,2-DCE was detected at locations 13-MW-6, 13-MW-7, 14-MW-3, 14-B-3 at concentrations ranging from 0.3 µg/L to 2.7 µg/L. The highest *trans*-1,2-DCE concentrations were detected near the bottom of the saturated zone at well 13-MW-7, located on the east side of the lake, and at the top of the saturated zone from boring 14-B-3, located downgradient of the lake.

TCE was detected at locations 13-MW-6, 13-MW-7, and boring 14-B-3 at concentrations ranging from 0.19 μg/L near the top of the saturated zone at boring 14-B-3 to 1,200 μg/L near the bottom of the saturated zone at well 13-MW-7.

Vinyl chloride was detected at a concentration of 7 μg/L in one discrete depth groundwater sample collected from the top of the saturated zone from 14-MW-3 (Tetra Tech 2003b)

In summary, the extent of chlorinated solvents detected in groundwater at the site cluster has been assessed and extends as far upgradient as 13-MW-3 and as far downgradient as 14-MW-6 and 14-MW-7, which are approximately 150 feet west of the Southern Pacific Railroad and 1,200 feet northwest of Watt Road, respectively (Figure 2-3).

2.2.4 Treatability Study

Tetra Tech completed a treatability study, which was initiated in fall 2003. The objective of this study was to provide sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analyses, to support the remedial design of a selected alternative, and reduce the cost and performance uncertainties for treatment alternatives to acceptable levels so that a final remedy can be selected. The treatability study was conducted to assess the ability of Hydrogen Release Compound, Extended Release Formula (HRC-X) and Primer (a lactic acid product) to enhance already semi-anaerobic conditions within a portion of the aquifer at Watt Road, and anaerobically degrade 1,1-DCE, *trans* 1,2-DCE, *cis*-1,2-DCE, and vinyl chloride from groundwater near wells 14-MW-3, 14-MW-9, and 14-MW-10. The area selected for the treatability study is characterized by naturally moderately reducing conditions and contains DCE isomers and vinyl chloride at concentrations ranging from tens to hundreds of micrograms per liter. The Groundwater Treatability Study Report is presented in Appendix A.

On 11 through 12 November 2003, HRC-X and Primer was injected into six injection wells (wells 14-INJ-1 through 14-INJ-6) positioned upgradient from monitoring wells 14-MW-3, 14-MW-9, and 14-MW-10 in the paleochannel at Site 13C (Figure 2-5). Upgradient well 14-MW-2, located near the western edge of ABRES-A Lake, was also monitored to support the treatability study. Inferred groundwater flow direction to the northwest was verified during March 2004 with a lake level measurement.

Results for the first 9 months of monitoring indicate that subsurface aquifer conditions have been appropriately changed to strongly reducing in deep aquifer wells, with a resultant decline in targeted constituent concentrations (primarily *cis*-1,2-DCE) through complete degradation to ethane and ethane (the end products of sequential dechlorination of the parent compound DCE), without a buildup of the intermediate daughter product, vinyl chloride, above historically measured levels. Detectable metabolic acids in monitoring wells indicate breakdown of HRC-X and Primer in the treatment zone. This process provides the hydrogen ions necessary for microbes to degrade chlorinated solvents present in the zone of influence. In addition, various water quality parameters (i.e., dissolved oxygen, oxidation-reduction potential, sulfide, etc.) support an interpretation of enhanced reductive dechlorination conditions. The injection zone and associated wells will continue to be monitored quarterly during the BGMP. Results from BGMP sampling between fall 1997 and summer 2003 are provided in Table 2-3.

2.2.5 Previous Remedial Actions

No previous remedial actions have been performed at Site 13C.

2.2.6 Source and Extent of Contamination

The primary sources of existing solvent contamination in groundwater at Site 13 Cluster are believed to be associated with the former ABRES-A launch activities. Deluge water potentially contaminated with TCE and possibly other solvents was discharged down the deluge channels directly into ABRES-A Canyon and ABRES-A Lake. Chlorinated solvents have been consistently detected in groundwater as far upgradient as monitoring well 13-MW-2 and as far downgradient as paired wells 14-MW-6 and 14-MW-7. Groundwater monitoring results over the course of the RI indicate that TCE is completely degraded to DCE and vinyl chloride as groundwater moves beneath ABRES-A Lake and enters the paleochannel near wells 14-MW-1 and 14-MW-2. Monitored Natural Attenuation (MNA) parameters support an interpretation of reductive dechlorination in the vicinity of wells 14-MW-1 through 14-MW-3. Elevated concentrations of *cis*-1,2-DCE exceeding the California Maximum Contaminant Level (MCL) of 6 μg/L have been detected in groundwater that flows under ABRES-A Lake into the buried paleochannel downgradient of ABRES-A Lake. Although natural attenuation processes appear to be sufficient to reduce TCE to concentrations below detectable levels at the west margin of ABRES-A Lake, natural attenuation processes in the dune sand aquifer downgradient of the lake do not appear to be sufficient to naturally reduce DCE and vinyl chloride levels below their respective MCLs (Tetra Tech 2004a).

Based on the available data, the groundwater plume is approximately 3,500 feet in length, extending from monitoring well 13-MW-2 to paired wells 14-MW-6 and 14-MW-7. The groundwater aquifer at the Site 13C occurs in a narrow paleochannel and the plume is assumed to extend across its entire width, which averages about 150 feet.

Currently, *cis*-1,2-DCE concentrations in the source area and in the paleochannel are in the hundreds of micrograms per liter and decrease by an order of magnitude to non-detect at wells downgradient of 14-MW-4. Vinyl chloride was detected near the source area at concentrations up to 51.9 μg/L and the highest average vinyl chloride concentrations (up to 49.3 μg/L) have been detected in the transition zone between ABRES-A Lake and the paleochannel at wells 14-MW-2 and 14-MW-3. Concentrations of both *cis*-1,2-DCE and vinyl chloride remain highest along the bottom of the paleochannel although lower concentrations are still detected along the top of the saturated unit as far downgradient as monitoring well 14-MW-4 (Figure 2-4).

No dense non-aqueous phase liquids (DNAPLs) have been encountered during any of the field investigations at the site cluster. Measured concentrations in soil and groundwater in the canyon are below levels that suggest the presence of TCE or *cis*-1,2-DCE as DNAPLs. Therefore, there is no indication that DNAPLs currently exist at the Site 13 Cluster (Tetra Tech 2003b).

2.3 FATE AND TRANSPORT MODELING

The objective of the groundwater modeling is to provide predicted contaminant concentrations at the limit of the site groundwater monitoring network (e.g., sentry well 14-MW-5). The modeling also quantitatively demonstrates the impacts of attenuation processes (i.e., advection, dispersion, and degradation) on the future evolution of the DCE and vinyl chloride groundwater plumes. The groundwater modeling was performed using U.S. Geological Survey (USGS) MODFLOW software. A version of MODFLOW that includes the Lake Package was used in order to more correctly simulate the interaction between the groundwater and ABRES-A Lake. Groundwater fate and transport was simulated using the Modular Three Dimensional Transport Model (MT3D) and the Multi-Species Reactive Transport Simulation Software (RT3D) model. RT3D is based on the MT3D model, which uses a mixed Eulerian-Lagrangian approach to the solution of the advection-dispersion equation, based on a combination of the method of characteristics and the modified method of characteristics. RT3D adds the capability to simulate various types of chemical and microbial reaction kinetics. For Sites 13 and 14, the first-order sequential decay model for TCE, DCE, and vinyl chloride decay chain components (RT3D Reaction Module 6) was used to simulate biodegradation.

The winter 2003 VOC concentrations were used to simulate the impact on groundwater quality at sentry well 14-MW-5 if a hydrogen donor treatment compound is injected into site groundwater using RT3D. The RT3D simulations were run separately for treatment injections at wells 14-MW-3, 14-MW-4, and 14-MW-6, wells located progressively further down the paleochannel and approaching the sentry wells. Results of the RT3D simulations are summarized on Figure 2-6. These scenarios were run to evaluate the location at which an injection array would best prevent VOCs at concentrations above the California drinking water MCLs from impacting groundwater at sentry wells 14-MW-5 and 14-MW-8 (Tetra Tech 2003b).

2.3.1 Modeling Summary for Natural Attenuation of DCE and Vinyl Chloride in the Paleochannel

The groundwater model predicts that the plume will migrate over the next several decades toward sentry well 14-MW-5. Using winter 2003 monitoring data, concentrations of *cis*-1,2-DCE and vinyl chloride at sentry well 14-MW-5 are predicted to peak at 84 µg/L (by 2031) and 3.5 µg/L (by 2029), respectively (Figure 2-6). Without active remediation, concentrations of *cis*-1,2-DCE at the sentry well will fall below the California MCL or 6 µg/L by approximately 2065. Under the natural attenuation scenario, vinyl chloride will fall below the California MCL of 0.5 µg/L by approximately 2055 at sentry well 14-MW-5. Thus, natural attenuation processes are not strong enough to decrease concentrations of *cis*-1,2-DCE and vinyl chloride at the sentry well below the MCLs within a reasonable timeframe

For the modeling scenario where only one area near 14-MW-3 is treated with HRC, subsurface conditions at sentry well 14-MW-5 are predicted to exceed the California MCLs of 6 µg/L for *cis*-1,2-DCE and 0.5 µg/L for vinyl chloride by approximately 2010. This scenario predicts that concentrations of DCE and vinyl chloride at the sentry well will peak at 30 µg/L (by 2024) and 1.2 µg/L (by 2022), respectively (Figure 2-6). The RT3D model was then run with another hypothetical treatment barrier at well 14-MW-4. Under this scenario, DCE concentrations at the sentry well still exceed the California MCL but vinyl chloride concentrations do not. When the model is performed with an additional treatment with HRC farther downgradient near well 14-MW-6, both DCE and vinyl chloride levels are reduced sufficiently to prevent concentrations DCE and vinyl chloride above the MCLs from impacting the sentry well (Figure 2-6). Results of this modeling scenario indicate that the IRA should focus on at least two treatment areas (e.g., injection barriers) in order to completely mineralize the VOCs and to prevent VOCs from migrating to the sentry well location (Tetra Tech 2003b).

2.4 HUMAN HEALTH STREAMLINED RISK EVALUATION

A streamlined risk evaluation was conducted for the Site 13C Draft RI (Tetra Tech 2004a) in order to evaluate potential carcinogenic risks and noncarcinogenic hazards associated with chlorinated solvents in groundwater. The exposure scenarios are consistent with guidelines provided in the U.S. EPA *Risk Assessment Guidance for Superfund* (U.S. EPA 1989), the California Environmental Protection Agency (Cal/EPA) *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (Department of Toxic Substances Control [DTSC] 1992) and guidance on the dermal exposure pathway (DTSC 2000). Cal/EPA's *Preliminary Endangerment Assessment Guidance Manual* (DTSC 1999) was also used to guide the risk assessment.

The focus of this study is an evaluation of TCE and its daughter products in groundwater. The compounds TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride are identified as chemicals of potential concern (COPCs) for this study. The monitoring data used to characterize groundwater conditions for streamlined risk evaluation were based on data collected in 1997 and 2000. Metals detected in groundwater are being addressed in the baseline risk assessment, as are the five other organic chemicals that are considered likely to be laboratory artifacts (i.e., acetone, 2-butanone, carbon disulfide, chloroform, and methylene chloride) (Tetra Tech 2003b).

Three human receptor groups were assumed to be exposed to groundwater: future industrial workers, future construction workers, and off-site residents. Total excess lifetime carcinogenic risks estimated for industrial workers, construction workers, and off-site residents exposed to COPCs in groundwater are approximately 2×10^{-4}, 2×10^{-5}, and 2×10^{-3}, respectively. These risk estimates exceed the DTSC "point of departure" of 10^{-6} and risks for off-site residents exceed the U.S. EPA's target risk range of 10^{-6} to 10^{-4}. The noncarcinogenic Hazard Index (HI) for industrial and construction workers is 2.8 and 5.6, respectively. The overall HI for hypothetical use of groundwater for off-site residents is approximately 35 for adults and 140 for children. All of these HIs exceed the threshold value of 1.

In summary, the results of the streamlined human health risk assessment suggest that four of the five chlorinated solvents found in groundwater (TCE, *cis*-1,2-DCE, 1,1-DCE, and vinyl chloride) pose non-negligible risks to three hypothetical human receptor groups assumed to use groundwater for potable purposes. Based on these results, additional action appears warranted at this site cluster.

2.5 ECOLOGICAL RISK ASSESSMENT SUMMARY

An ERA was conducted as part of the Site 13C Draft RI (Tetra Tech 2004a). Ecological risks were evaluated for four areas of concern (AOCs) at Sites 13, 14, and 28: (1) the Mesa, which consists of coastal sage scrub habitat on the Sites 13 and 28, and as well as three seasonally wet artificial basins (neutralization lagoon, lower nitrogen tetroxide hardstand, and lower Aerozine-50 hardstand) offering limited aquatic habitat, (2) riparian habitat in ABRES-A Canyon, (3) freshwater emergent/aquatic habitat at ABRES-A Lake, and (4) All Terrestrial Areas of Sites 13, 14, and 28, which was evaluated for wide-ranging species that forage across the whole site cluster.

Ecological Hazard Quotients (HQs) of significance in the Mesa AOC consisted of potential risks to plants posed by lead in surface soils, potential risks to plants and herbivorous small mammals posed by molybdenum in soils, and potential risks to soil invertebrates and herbivorous birds posed by zinc in surface soils. In the VOC hotspot at Channel C, the HQ for inhalation exposures of the ornate shrew to TCE in subsurface soils slightly exceeded 1. In the neutralization lagoon, zinc in surface water and selenium in sediments pose a potential for adverse effects on aquatic invertebrates and emergent plants, respectively, although these HQs were both less than 2. In the lower nitrogen tetroxide hardstand, a potential exists for adverse impacts to aquatic invertebrates due to exposures to lead in surface water, to emergent plants due to exposures to lead and zinc in sediments, and to sediment biota due to exposures to cadmium, copper, lead, nickel, and zinc in sediments. The overall marginal to moderate ecological value of these habitats should be considered when making risk management decisions about the neutralization lagoon and lower nitrogen tetroxide hardstand. In the ABRES-A Canyon AOC, a potential exists for adverse impacts to terrestrial receptors due to exposures to cadmium (grasses and forbs and shrubs), lead (grasses and forbs, shrubs, trees, and soil invertebrates), molybdenum (grasses and forbs, shrubs, trees, and herbivorous mammals), and zinc (grasses and forbs, shrubs, soil invertebrates, insectivorous birds, and herbivorous birds and mammals). In the ABRES-A Lake AOC, a potential exists for adverse impacts to emergent plants due to exposures to cadmium, molybdenum, and selenium in sediments, and to sediment biota due to exposures to cadmium and nickel in sediments.

3.0 REMOVAL ACTION SCOPE AND OBJECTIVES

3.1 STATUTORY LIMITS

The identification process must include consideration of statutory limits on removal actions. The statutory limits on removal actions are $2 million for fund-financed removal actions pursuant to section 104(c)(l) of CERCLA. It is highly unlikely that this limit will be exceeded, as costs for this removal action are anticipated to be considerably less than $2 million. The time necessary to complete this action is contingent upon regulatory approval and public comment period.

3.2 CONDITIONS JUSTIFYING REMEDIAL ACTION

3.2.1 Review of Regulations

A review of applicable regulations concerning DCE, TCE, and vinyl chloride contamination in the environment revealed the following information.

The maximum concentrations of TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride detected in groundwater at Site 13C during the RI were 1,300, 1,580, 21, 6.71, and 51.9 µg/L, respectively (Table 2.3). The maximum concentration of TCE detected in groundwater (1,300 µg/L) exceeds the Resource Conservation and Recovery Act (RCRA) hazardous waste Toxics Characteristics Leaching Procedure (TCLP) criterion of 500 µg/L. This elevated concentration of TCE was detected in groundwater upgradient of ABRES-A Lake; only trace (less than 1 µg/L) concentrations of TCE have been detected in the paleochannel where the groundwater IRA is proposed. Concentrations of other organic constituents in site groundwater do not exceed California or federal hazardous waste criteria. These hazardous waste criteria, along with other ARARs applicable to groundwater, are provided in Appendix B.

The Central Coast Water Quality Control Plan (1994) sets water quality objectives for the central coast of California and protects the beneficial uses of water at Vandenberg AFB pursuant to Title 22 of the California Code of Regulations (CCR). The Plan identifies all groundwater within the central coast to be of potential beneficial use. To protect the beneficial use of groundwater, TCE, *trans*-1,2-DCE, 1,1-DCE, *cis*-1,2-DCE, and vinyl chloride should not exceed the California MCLs of 5, 10, 6, 6, and 0.5 µg/L, respectively. Concentrations of *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride exceed the California MCLs in paleochannel groundwater. The VOCs TCE and 1,1-DCE were not detected at concentrations above the MCLs in the paleochannel area.

State Water Resources Control Board (SWRCB) Resolutions 68-16 and 92-49 require that high quality groundwater be maintained to the maximum extent possible. During preparation of the Groundwater Treatability Study Work Plan for Site 13C, the SWRCB commented on the Draft document that

> "Cleanup of sites must be in manner that promotes the attainment of either background water quality, or the best water quality that is reasonable if background water quality cannot be restored."

Given this requirement, the Air Force will continue to evaluate final cleanup levels, including the technical and economical feasibility of alternatives to achieve background (i.e., nondetectable levels) for all VOCs in groundwater. These final cleanup levels will be addressed in the forthcoming Feasibility Study for Site 13C.

3.2.2 Fate and Transport Modeling Summary

The fate and transport modeling predicts that the groundwater plume in the paleochannel will migrate over the next several decades toward sentry well 14-MW-5. Using winter 2003 monitoring data, the concentration of *cis*-1,2-DCE at sentry well 14-MW-5 is estimated to peak at 84 µg/L by 2031; similarly, the concentration of vinyl chloride is estimated to peak at 3.4 µg/L by 2029. Without active remediation, concentrations of *cis*-1,2-DCE at the sentry well are estimated to fall below the California MCL (6 µg/L) by approximately 2065. Under the natural attenuation scenario, vinyl chloride is estimated to fall below the California MCL of 0.5 µg/L by approximately 2055 at the sentry well (Figure 2-6). Therefore, natural attenuation processes are not considered adequate in decreasing *cis*-1,2-DCE and vinyl chloride concentrations at the sentry well below the MCLs within a reasonable timeframe.

Results of the active remediation modeling scenario indicate that an IRA should focus on at least two treatment areas in order to mineralize the VOCs to concentrations below MCLs and to prevent VOCs from migrating to the sentry well location (Tetra Tech 2003b).

3.2.3 Human Health Risk Summary

The results of the streamlined human health risk assessment suggest that four of the five chlorinated solvents found in groundwater (1,1-DCE, *cis*-1,2-DCE, TCE, and vinyl chloride) pose non-negligible risks to receptors assumed to use groundwater for potable purposes. Assumed exposure to *cis*-1,2-DCE and TCE results in noncancer HIs greater than 1, while exposure to 1,1-DCE, TCE, and vinyl chloride results in total carcinogenic risk estimates between 2×10^{-5} and 2×10^{-3}. Based on these results, additional action appears warranted at this site cluster.

3.2.4 Summary

The following IRA objectives for groundwater at the downgradient paleochannel portion of this site cluster have been identified:

- Control migration of the groundwater contaminant plume in the paleochannel until the final remedy for the source area is in place
- Begin reduction of VOC contaminant concentrations in the paleochannel aquifer to accelerate the final remedy.
- Prevent VOCs from impacting groundwater at sentry wells 14-MW-5 and 14-MW-8.
- Prevent potable uses of groundwater with chlorinated solvent concentrations that represent unacceptable levels of risk and exceed ARARs; and
- Remediate groundwater to conform to beneficial uses as designated by the Regional Water Quality Control Board (RWQCB), which includes consideration of drinking water MCLs

Based on the potential risks to receptors assumed to use groundwater for potable purposes, and results of the review of applicable regulations, it is recommended that the groundwater in the paleochannel be remediated because:

- Concentrations of *cis*-1,2-DCE, *trans*-1,2-DCE and vinyl chloride in the paleochannel groundwater currently exceed the proposed remediation goals (i.e., the California MCLs).

- The concentrations of *cis*-1,2-DCE at sentry well 14-MW-5 is estimated to peak at 84 µg/L by 2031; the concentration of vinyl chloride is estimated to peak at 3.4 µg/L by 2029.

- Total carcinogenic risks for exposure to TCE, DCE, and vinyl chloride levels in groundwater exceed the U.S. EPA's target risk range of 10^{-6} to 10^{-4}; and

- The overall noncarcinogenic HI for hypothetical use of groundwater as a potable water source exceeds 1.

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4.0 IDENTIFICATION AND SCREENING OF ALTERNATIVES

The following IRA alternatives for groundwater at Site 13C have been identified and screened:

- Alternative 1: No Action;
- Alternative 2: Monitored Natural Attenuation;
- Alternative 3: *In-Situ* Bioremediation;
- Alternative 4: *In-Situ* Chemical Oxidation; and
- Alternative 5: *Ex-Situ* Groundwater Treatment.

The alternatives listed above were analyzed to determine their effectiveness in achieving the removal action objectives and estimated IRA duration Each of the alternatives was conceptually deployed at two locations along the paleochannel at Watt Road and west of the railroad tracks in order to achieve cleanup objectives.

The estimated duration of operation for active remedies (i.e., no action and MNA are excluded) was calculated using site-specific hydrogeologic data and geometric considerations. From the MODFLOW computer model used for the site cluster, the groundwater velocity beneath ABRES-A Lake is estimated as 0.4 feet/day, whereas the groundwater velocity beneath the paleochannel is estimated as 1.2 feet/day (Tetra Tech 2004a). Travel time is calculated by dividing the distance between the source area and the treatment area by the groundwater velocity. The distance between the Site 13 source area (taken as east of wells 13-MW-1 and -7) and the Watt Road treatment area is approximately 1,900 feet. This distance divided by the velocity of groundwater yields 4,750 days, or approximately 13 years

It has been assumed that the Site 13 source area will be removed during the Remedial Action-Construction (RA-C) 3 years henceforth. Therefore, in 3 years, an additional 13 years of travel time would be required before residual contamination in groundwater assumed to be positioned at the source area location flows beneath Watt Road to be treated. A total of 16 years (3 plus 13 years) would be required for active remedies at the Watt Road location.

The distance between Watt Road (assumed as a source area for the paleochannel) and the downgradient railroad treatment area is approximately 1,590 feet. At 1.2 feet/day, a total of 1,325 days, or approximately 3.6 years, is calculated as the time it would take for residual contamination to move from Watt Road to the downgradient treatment area. Assuming groundwater cleanup at Watt Road takes 2.4 years, a total of 6 years (2.4 plus 3.6 years) is calculated to be required to operate a remediation system at the downgradient treatment area.

Since each active removal alternative screened in this EE/CA is designed to operate as a barrier, each alternative would be dependent upon travel times for contamination to reach the barrier. Therefore, alternatives at the downgradient treatment area are uniformly assumed to require 6 years of operation; while alternatives at the Watt Road treatment area are assumed to require 16 years of operation.

4.1 IDENTIFICATION OF SCREENING CRITERIA

California's Health and Safety Code Section 25356 1(d) requires that Removal Action Plans be based on the NCP. The NCP identifies nine criteria, or standards, that can be used to evaluate remedial alternatives. Because the nine criteria provide a thorough, standardized method for comparing alternatives, they are used for the Site 13C EE/CA. The nine criteria, as modified by the State of California, are listed below.

1. **Overall Protection of Human Health and the Environment**
   Addresses whether a remedy provides adequate protection of human health and the environment and describes how risks posed through each pathway are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls.

2. **Compliance with State and Federal Requirements**
   Addresses whether a remedy will meet all appropriate federal, state, and local environmental laws and regulations. This evaluation is a step to identify potential ARARs. **Applicable requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal, state, or local laws that specifically address the situation at a CERCLA site. The requirement is applicable if the jurisdictional prerequisites of the standard show a direct correspondence when objectively compared to the conditions at the site. If the requirement is not legally applicable, then the requirement is evaluated to determine whether it is relevant and appropriate. **Relevant and appropriate requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal, state, or local laws that, while not applicable, address problems or situations sufficiently similar to the circumstances of the proposed response action, and are well suited to the conditions of the site (U.S. EPA 1988). ARAR determination is an iterative process that requires the Air Force, as the lead federal agency, and the state to work together to identify and consider ARARs at critical points of the remedial process

   Tabulated summaries of potential ARARs for Site 13C groundwater are presented in Appendix B.

3. **Long-Term Effectiveness and Permanence**
   Refers to the ability of a remedy to maintain reliable protection of human health and the environment over time, once cleanup goals have been met.

4. **Reduction of Toxicity, Mobility, and Volume Through Treatment**
   Refers to the ability of a remedy to reduce the toxicity, mobility, and volume of the hazardous substances or constituents present at the site.

5. **Cost: Present Worth**
   Evaluates the estimated present-worth costs of each remedy including capital, operation, and maintenance costs.

6. **Short-Term Effectiveness**
Addresses the period of time needed to complete the remedy and any potential adverse impact to human health and the environment during the construction and implementation period until the cleanup standards are achieved.

7. **Implementability**
Refers to the technical and administrative feasibility of a remedy, including the availability of materials and services needed to carry out a particular option.

8. **Regulatory Agency Acceptance**
Indicates whether, based on its review of the information, the applicable regulatory agencies would agree with the preferred alternative.

9. **Community Acceptance**
Indicates whether the remedy addresses community concerns, and if the community prefers a specific remedy

For an alternative to be eligible for selection, it must meet the first two "threshold" criteria described above. Criteria 3 through 7 are the "primary balancing criteria," and criteria 8 and 9 are "modifying criteria" (DTSC 1995). The NCP (40 Code of Federal Regulations [CFR] 300.403[e]) provides further discussion on the use of these criteria.

4.2 SCREENING OF REMEDIAL ALTERNATIVES

This section evaluates the removal alternatives based upon the NCP criteria

4.2.1 Alternative 1: No Action

Alternative 1 is a baseline scenario to which other management alternatives can be compared. Under Alternative 1, no removal action or institutional controls would be administered

4.2.1.1 Overall Protection of Human Health and the Environment

The SWRCB Resolution 68-16 establishes the policy that high-quality waters of the State shall be maintained to the maximum extent possible "consistent with the maximum benefit to the people of the State" (SWRCB 1994). This requirement has been interpreted for this EE/CA to apply to any groundwater that may have future beneficial use for the people of the State. Alternative 1 would not provide any means for improvement of the groundwater and therefore does not address the protection of human health and the environment. Therefore, the no-action alternative does not meet the first of the two threshold criteria.

4.2.1.2 Compliance with State and Federal Requirements

The no-action alternative would not serve to reduce contamination levels toward achieving ARARs at Site 13C. Therefore, Alternative 1 does not meet the second of the two threshold criteria and will not be evaluated further.

4.2.2 Alternative 2: Monitored Natural Attenuation

For Alternative 2, numerous physical and chemical groundwater parameters would be periodically monitored to assess the potential for intrinsic biodegradation of chlorinated solvents Anaerobic conditions (low dissolved oxygen and negative oxidation reduction potential) are favorable for the initial degradation of TCE and its daughter products. Where MNA potential is high and where an imminent risk to human health and the environment does not exist, MNA may be the remediation method of choice for groundwater contaminated with petroleum hydrocarbons or chlorinated ethenes. MNA is accepted by the U.S. EPA and all states when supported by field data Implementation is usually straightforward and operation and maintenance (O&M) involves well maintenance, a monitoring schedule, and project reporting. If implemented, MNA could be used as the sole remedy, or as part of a more complex remediation strategy. Note that at Site 13C, MNA is currently performed under the BGMP.

Degradation of TCE via reductive dechlorination is likely occurring at Sites 13 and 14, based on the presence of TCE degradation products DCE and vinyl chloride in groundwater, the fact that there were no suspected uses of DCE and vinyl chloride at Site 13C, and the disappearance of TCE below ABRES-A Lake with continued detections of DCE and vinyl chloride in paleochannel wells The absence of TCE and the persistence of DCE and vinyl chloride as the plume migrates downgradient suggest that TCE degradation rates are relatively high, but that the DCE and vinyl chloride degradation rates are relatively low. The fate and transport modeling summarized in Section 2.3 demonstrates the effects of the natural attenuation processes on the future evolution of the DCE and vinyl chloride groundwater plumes at Site 13C. The fate and transport modeling indicates that natural attenuation processes would not be adequate to decrease *cis*-1,2-DCE and vinyl chloride concentrations at the sentry well below the MCLs within a reasonable timeframe.

4.2.2.1 Overall Protection of Human Health and the Environment

The SWRCB Resolution 68-16 establishes the policy that high-quality waters of the State shall be maintained to the minimum extent possible "consistent with the maximum benefit to the people of the State" (SWRCB 1994). This requirement has been interpreted for this EE/CA to apply to any groundwater that may have future beneficial use for the people of the State. Alternative 2, based on computer modeling, would result in MCL exceedances at the sentry wells and would not provide for improvement of groundwater conditions and protection of human health and the environment. Therefore, the MNA alternative does not meet the first of the two threshold criteria.

4.2.2.2 Compliance with State and Federal Requirements

The fate and transport modeling summarized in Section 2.3 demonstrated that natural attenuation processes would not be adequate in decreasing *cis*-1,2-DCE and vinyl chloride concentrations at the sentry well below the MCLs within a reasonable timeframe. Contaminant transport modeling indicates that *cis*-1,2-DCE levels will fall below the California MCL of 6 µg/L by approximately 2065 and vinyl chloride will fall below the California MCL of 0.5 µg/L by approximately 2055 at sentry well 14-MW-5. Because Alternative 2 would not reduce contamination levels below MCLs within a reasonable amount of time, this alternative does not meet the second of the two threshold criteria and will not be evaluated further.

4.2.3 Alternative 3: *In-Situ* Bioremediation

In-situ bioremediation is a remediation technology that utilizes naturally occurring microorganisms to convert organic contaminants into simpler compounds under manipulated environmental conditions. The microorganisms can degrade undesirable organic compounds such as TCE, *cis*-1,2-DCE, and vinyl chloride. *In-situ* bioremediation is applied to environmental contaminants to eliminate or reduce the toxicity of the contaminants and thus reduce the risk to human health and the environment. The innovative aspect of this technology is the appropriate and preconceived manipulation of environmental conditions to promote or enhance biodegradation of compounds that are otherwise undergoing little or no natural biodegradation. Bioremediation techniques are destruction techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source (O'Brien and Gere Engineers, Inc. [O'Brien and Gere] 1995) Alternative 3 would involve the injection or addition of electron donors and/or electron acceptors into the groundwater aquifer to enhance the ability of microorganisms to degrade specific contaminants. Through *in-situ* bioremediation, it is expected that *cis*-1,2-DCE and vinyl chloride would be degraded and destroyed. Technologies that are included in the evaluation of *in-situ* bioremediation are injection of HRC and/or Oxygen Release Compound (ORC), addition of oxygen and hydrogen gas to the subsurface, and addition of soybean oil. For the initial screening, injection of HRC and ORC was assumed to comprise the *in-situ* bioremediation program.

4.2.3.1 Overall Protection of Human Health and the Environment

Performing *in-situ* bioremediation would likely eliminate existing unacceptable risks due to potential current and future human receptors as stated by SWRCB Resolution 68-16. With regard to the environment, equipment operation associated with remedial activities would cause a short-term disturbance of vegetation and animals at Site 13C (e.g., with the installation of groundwater monitoring and/or injection wells, application [injection of electron donor or acceptor product], and regular O&M activities). Short-term impacts will be mitigated with access control measures during the field activities.

4.2.3.2 Compliance with State and Federal Requirements

Tabulation of potential ARARs identified for Site 13C are provided in Appendix B. If applied successfully, Alternative 3 would comply with the federal, state, and local requirements presented in these tables.

4.2.3.3 Long-Term Effectiveness and Permanence

The final, long-term remedy for the source area at Site 13C will be addressed during the RA-C after completion of the FS. The *in-situ* bioremediation alternative will likely be effective over the long term in reducing VOC concentrations in the paleochannel downgradient of the source area; thus protecting the beneficial uses of the aquifer.

4.2.3.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

This alternative would involve the manipulation of the subsurface environment to facilitate contaminant degradation. Contamination moving through the groundwater would be degraded based on the amendments added. Contaminant levels would be reduced and would be prevented from moving downgradient; therefore, the toxicity, mobility, and volume of contamination would be reduced to achieve acceptable risk levels at Site 13C.

4.2.3.5 Cost: Present Worth

The estimated present-worth cost associated with *in-situ* bioremediation at Site 13C is $5,021,935. A detailed breakdown of this cost is provided in Appendix D. This cost assumes a total project duration, including O&M, of 16 years. The basis for the 16-year duration is provided in Appendix D.1

4.2.3.6 Short-Term Effectiveness

After amending the subsurface environment, it would likely require several months for the groundwater environment to be suitably affected. This is due to the time required for either electron donors or acceptors to disperse in the groundwater. Also, after dispersion, it is expected that additional time would be required for the subsurface microorganisms become acclimated to the environment. During installation of Alternative 3, short-term risks associated with the use of heavy equipment would be created, including movement of drill rigs around the site. A Health and Safety Plan, included as Appendix C, addresses removal action hazards, but this administrative tool will not eliminate all site hazards. Ecological resources would be affected by traffic to and from the site, and by drilling and installation equipment. Implementing access control measures during the field activities will minimize these short-term impacts.

4.2.3.7 Implementability

Implementing *in-situ* bioremediation would be administratively and technically feasible. Materials, equipment, and services necessary for this alternative would be readily available. Implementing this alternative would involve drilling and well installation subcontractors, amendment application/injection subcontractors, and laboratory subcontractors.

4.2.3.8 Regulatory Agency Acceptance

Although regulatory agency acceptance of this alternative is anticipated, Tetra Tech and the Air Force would work closely with DTSC and the RWQCB, as needed, during the approval process. In addition, all pertinent ARARs are listed in Appendix B.

4.2.3.9 Community Acceptance

Community acceptance of this alternative would be expected because treatment of the contaminated groundwater would protect the beneficial use of the paleochannel aquifer. The groundwater would be treated in place. Minimal but manageable impacts to the environment would be expected during the installation and operation phases of this alternative. Impacts to local traffic from this alternative would be minimal and would include subcontractors entering and leaving Vandenberg AFB during field activities.

4.2.4 Alternative 4: *In-Situ* Chemical Oxidation

Oxidation is the movement of a contaminant to a higher oxidized or more environmentally benign state. The oxidation process can transform many chemicals that are considered contaminants in the environment into innocuous end products. Over time, the injected oxidant is depleted, requiring additional injections. Oxidation technologies form part of the many treatment alternatives that, when applied effectively at a hazardous waste site, have the capability to reduce or eliminate both the volume and toxicity of contaminants (O'Brien and Gere 1995). The most common delivery methods of *in-situ* chemical oxidation (ISCO) involve injection of the oxidant only (Naval Facilities Engineering Services Center

[NFESC] 2004). The technology that is included in the discussion of ISCO is the injection of potassium permanganate solution

4.2.4.1 Overall Protection of Human Health and the Environment

Performing ISCO would likely eliminate existing unacceptable risks due to potential current and future human receptors as stated by SWRCB Resolution 68-16. With regard to the environment, equipment operation associated with removal activities would cause a short-term disturbance of vegetation and animals at Site 13C (e.g., with the installation of groundwater monitoring and/or wells, injection of additives, and regular O&M activities). Short-term impacts will be mitigated with access control measures during the field activities.

4.2.4.2 Compliance with State and Federal Requirements

Tabulation of potential ARARs identified for Site 13C are provided in Appendix B. If applied successfully, Alternative 4 would comply with the federal, state, and local requirements presented in these tables.

4.2.4.3 Long-Term Effectiveness and Permanence

The final, long-term remedy for the source area groundwater at Site 13C would be addressed during the RA-C after completion of the FS. Over the long term, the ISCO alternative would be effective over the long term in reducing VOC contamination in the paleochannel aquifer, thus protecting the beneficial use of the groundwater aquifer. This technology is not permanent by design. To ensure long-term effectiveness, this technology would require repeated injection of product to maintain oxidant levels required for treating chlorinated solvents in the groundwater (i.e., every 120 days).

4.2.4.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

This alternative would involve the addition of chemical oxidants to groundwater in order to destroy chlorinated solvents. Chemical oxidants reduce the toxicity of contamination through complete destruction, thus preventing the VOCs from migrating downgradient to the sentry well. Therefore, the toxicity, mobility, and volume of contamination would be reduced to achieve acceptable risk levels at Site 13C.

4.2.4.5 Cost: Present Worth

The estimated present-worth cost associated with ISCO at Site 13C would be approximately $5,468,716. Breakdown of this cost can be seen in Appendix D. This cost assumes a total period of performance of 16 years.

4.2.4.6 Short-Term Effectiveness

After amending the subsurface environment, destruction of groundwater contaminants via ISCO would begin immediately. The time required to amend the subsurface environment is dependent on:

- Size of the treatment area;
- Oxidant delivery rates;

- Remediation goal; and
- Well spacing and aquifer properties (groundwater velocity).

This technology would be expected to begin oxidizing VOCs soon after injection into the groundwater. During this installation phase of Alternative 4, short-term risks associated with the use of heavy equipment would be created, including movement of drill rigs around the site. A Health and Safety plan is included as Appendix C so that workers can address removal action hazards, but this administrative tool will not eliminate all site hazards. Ecological resources would be affected by traffic to and from the site, and by drilling and installation equipment. Implementing access control measures during the field activities will minimize these short-term impacts.

4.2.4.7 Implementability

Implementing ISCO would be administratively and technically feasible. Materials, equipment, and services necessary for this alternative are readily available. Implementing this alternative would involve coordinating drilling contractors, oxidant injection, and laboratory subcontractors. Stainless steel casing would be required for all injection wells. The presence of high levels of organic peat material in the aquifer at Watt Road would increase oxidant demand and may require application of additional oxidant.

4.2.4.8 Regulatory Agency Acceptance

Although regulatory agency acceptance of this alternative is anticipated, Tetra Tech and the Air Force would work closely with DTSC and the RWQCB, as needed, during the approval process. Some additional monitoring requirements (i.e., color, manganese, etc.) may be imposed prior to regulatory approval. In addition, all pertinent ARARs are listed in Appendix B.

4.2.4.9 Community Acceptance

Community acceptance of this alternative would be expected because treatment of the contaminated groundwater would protect the beneficial use of the paleochannel aquifer. The groundwater would be treated in place. Minimal impact to the environment would be expected during the installation and operation phases of this alternative. Impacts to local traffic from this alternative would be minimal and would include subcontractors entering and leaving Vandenberg AFB each day.

4.2.5 Alternative 5: Ex-Situ Groundwater Treatment

Ex-situ groundwater treatment would involve extraction of groundwater to the surface, treating contamination, and then either recharging the treated water back into the ground or discharging the water to a surface water body or treatment/disposal unit such as a municipal sewage plant. Once groundwater has been pumped to the surface, contaminants can be reduced to very low levels with established technologies. Pumping and treating contaminated groundwater does not guarantee that all of the contaminants will be removed from the site. *Ex-situ* groundwater treatment can be designed along with containment, which will prevent the contamination plume from spreading, thus reducing the contamination mass. For containment, the extraction rate is generally established as the minimum rate sufficient to prevent migration of the contaminated zone. For restoration, the pumping rate is increased to allow clean water to flush more quickly through the contaminated zone. Once groundwater is extracted, the VOCs be removed from the effluent using a proven technology such as granular activated carbon. The evaluation for Alternative 5 is based on a containment strategy.

4.2.5.1 Overall Protection of Human Health and the Environment

Performing *ex-situ* groundwater treatment would eliminate existing unacceptable risks in water due to potential current and future human receptors as stated by SWRCB Resolution 68-16. Extracted water would be treated to required standards and would no longer pose a human health risk. Over time, contaminant concentrations in groundwater would be reduced through the extraction process. With regard to the environment, equipment operation associated with remedial activities would cause a short-term disturbance of vegetation and animals at Site 13C (e.g., with the installation of addition groundwater wells, and regular operation and maintenance activities) Short-term impacts will be mitigated with access control measures during the field activities.

4.2.5.2 Compliance with State and Federal Requirements

Tabulation of potential ARARs identified for Site 13 is provided in Appendix B. Alternative 5 would comply with the federal, state, and local requirements presented in these tables.

4.2.5.3 Long-Term Effectiveness and Permanence

The *ex-situ* groundwater treatment alternative would only be effective over the long-term operation of the system by reducing and potentially eliminating the potential current and future human health risk pathways associated with contaminated groundwater. This technology would be a long-term installation by design based on the time it would take to remove groundwater contaminants. To ensure long-term effectiveness, this technology would require continual operation of the extraction and treatment system to reduce chlorinated solvent concentrations in the groundwater

4.2.5.4 Reduction of Toxicity, Mobility, and Volume Through Treatment

This alternative would involve the extraction of contaminated groundwater The extraction process would create a hydraulic containment barrier, thus preventing migration of groundwater contamination toward the sentry well. Once extracted, the groundwater would be treated to remove VOCs. This process would reduce the toxicity of extracted groundwater and prevent it from migrating further downgradient. The volume of contamination in the subsurface would be reduced over time by creating a mass transfer gradient between groundwater and the aquifer material Therefore, the toxicity, mobility, and volume of contamination would be reduced to achieve acceptable risk levels at Site 13C.

4.2.5.5 Cost: Present Worth

The estimated present-worth cost associated with *ex-situ* groundwater treatment at Site 13C would be approximately $4,680,810. Breakdown of this cost can be seen in Appendix D. The cost assumes—and indicates—O&M for 16 years.

4.2.5.6 Short-Term Effectiveness

After startup of the groundwater extraction system, hydraulic containment and removal of contaminants would begin immediately. During installation of Alternative 5, short-term risks associated with the use of heavy equipment would be created, including movement of drill rigs around the site. A Health and Safety plan is included as Appendix C so that workers can address removal action hazards, but this administrative tool will not eliminate all removal action hazards. Ecological resources would be affected by traffic to and from the site, and by drilling and installation equipment Implementing access control measures during the field activities will minimize these short-term impacts.

4.2.5.7 Implementability

Implementing *ex-situ* groundwater treatment would be administratively and technically feasible, although permitting costs would be higher. Materials, equipment, and services necessary for this alternative are readily available. Implementing this alternative would involve coordinating drilling contractors, system design, installation, and maintenance, water treatment product change-out, and laboratory subcontractors. In addition, due to the required operation and maintenance of the treatment system, an increased amount of field labor would be necessary.

4.2.5.8 Regulatory Agency Acceptance

Although regulatory agency acceptance of this alternative is anticipated, Tetra Tech and the Air Force would work closely with DTSC and the RWQCB, as needed, during the approval process. In addition, all pertinent ARARs are listed in Appendix B

4.2.5.9 Community Acceptance

Community acceptance of this alternative would be expected because treatment of the contaminated groundwater would protect the beneficial use of the paleochannel aquifer. Treated groundwater would then be returned to the environment. Minimal impact to the environment would be expected during installation and operation of this action. Impacts to local traffic from this alternative would be minimal and would include subcontractors entering and leaving Vandenberg AFB during field activities.

4.3 COMPARISON OF SELECTED ALTERNATIVES

A screening table (Table 4-1) has been prepared to compare the selected alternatives in terms of short- and long-term effectiveness, implementability, and cost. These categories were assigned a number from 0 (the least desirable rank) to 3 (the most desirable rank). These numbers were added and a total rank was assigned to each alternative. Based on the comparison of effectiveness, implementability, and cost it was determined that Alternative 3, *in-situ* bioremediation, had the highest score and therefore would be the best technology for remediation of chlorinated solvents at Site 13C. Specific *in-situ* bioremediation alternatives for remediation of groundwater (i.e., electron donor and acceptor alternatives) are discussed in Section 4.6.

4.4 SUMMARY OF PREFERRED REMEDIAL ALTERNATIVE

Based on the evaluation of remedial alternatives, the preferred alternative is Alternative 3 (*in-situ* bioremediation). This alternative would reduce contaminant concentrations and would also comply with regulatory requirements and be protective of human health and the environment.

A detailed plan for implementation of *in-situ* bioremediation in the paleochannel will be presented in the Site 13C IRA Work Plan. An evaluation of the temporary risks and potential impacts to on-site workers and the environment associated with implementation of the IRA.

Table 4-1
Relative Ranking of Interim Removal Alternatives

Alternative	Short- and Long-Term Effectiveness	Implementability	Cost	Total Score
1. No Action	0	0	3	3
2. Monitored Natural Attenuation	1	2	2	5
3. *In-Situ* Bioremediation	2	3	2	7
4. *In-Situ* Chemical Oxidation	2	2	1	5
5. *Ex-Situ* Groundwater Treatment	2	2	2	6

Note: The number 0 indicated the least desirable rank; 3 denotes the highest

4.5 DETAILED SCREENING OF *IN-SITU* BIOREMEDIATION ALTERNATIVES

Alternatives for *in-situ* bioremediation are identified and compared in this section and are summarized below. The alternatives being evaluated for *in-situ* bioremediation are:

- Alternative 3.A: Addition of HRC-X;
- Alternative 3.B: Addition of HRC-X and ORC;
- Alternative 3.C: Emplacement of Diffusive Gas Emitters (*In-situ* Submerged Oxygen Curtain [iSOC]);
- Alternative 3.D: Addition of soybean oil; and
- Alternative 3.E: Diffusive Gas Emitters and soybean oil.

4.5.1 Screening of *In-Situ* Bioremediation Alternatives

This section compares alternatives for implementing the five *in-situ* bioremediation options at Site 13C. As discussed previously, the treatment duration for Alternatives 3.A through 3.E would be 16 years. All of the alternatives would involve installing injection and monitoring wells for the delivery of various amendment compounds to the subsurface and subsequent monitoring. The same injection and monitoring well network is assumed for all alternatives. The design specifics, including substrate quantities and well spacing details, will be addressed in the IRA Work Plan for Site 13 Cluster and are discussed in the subsequent sections to provide a uniform basis for comparing the alternatives.

4.5.1.1 Alternative 3.A: Addition of HRC-X

Regenesis, Inc. (Regenesis) manufactures HRC-X, a patented product used to stimulate anaerobic biodegradation of contaminated hydrocarbons in groundwater and soil. HRC-X is a polylactate ester designed to slowly release lactic acid to groundwater over a period of up to 3 to 5 years. The lactic acid is slowly biotransformed to pyruvic acid and subsequently to acetic and propionic acids, releasing hydrogen in each step. Naturally occurring microorganisms capable of reductive dechlorination use the hydrogen to remove chlorine atoms from chlorinated hydrocarbons (i.e., convert TCE to DCE to vinyl chloride to ethene). Reductive dechlorination is recognized as one of the primary attenuation mechanisms by which groundwater plumes of chlorinated solvents can be contained and/or remediated.

Based on the review of site groundwater data discussed previously, groundwater conditions downgradient of ABRES-A Lake near well 14-MW-3 are currently semi-anaerobic (Appendix A). For example, dissolved oxygen (DO) levels are less than 0.5 milligrams per liter (mg/L), oxidation/reduction potential (ORP) values are negative, nitrate levels are non-detect, and ferrous iron concentrations are greater than 1 mg/L. Sulfate levels, which exceed 200 mg/L in this area, may compete with the reductive pathway, requiring higher strength HRC-X to achieve complete breakdown of the chlorinated VOCs.

Two HRC-X zones would be considered for the paleochannel at Site 13C. The first zone would be located along the width of the paleochannel on the west side of Watt Road, as shown on Figure 4-1. The injection well barrier would utilize the three existing wells from the treatability study. Using a spacing of 10 feet, an estimated 12 additional injection wells would be drilled using sonic drilling technology, and an injection well would be completed at each location for the purpose of facilitating HRC-X injection into the saturated zone. Note that design specifics, including substrate quantities and well spacing details, will be addressed in the IRA Work Plan for Site 13 Cluster. The second zone would be located along the width of the paleochannel on the west side of the Southern Pacific Railroad tracks, as shown on Figure 4-2. Using a spacing of 10 feet, an estimated 15 injection wells would be drilled to refusal using sonic drilling technology, and HRC-X slurry would be injected throughout the saturated zone in this area. An additional 5 monitoring wells would be installed to permit monitoring of aquifer conditions in the vicinity of the HRC-X injection locations

Based on RT3D model predictions, two *in-situ* reactive zone (IRZ) injection zones, if successful in completely dechlorinating DCE isomers and vinyl chloride, would be sufficient for reducing VOC concentrations in groundwater immediately downgradient of Watt Road and preventing VOCs from exceeding MCLs at the sentry wells. A total of 87,900 pounds of HRC-X product is assumed to be injected into the injection well array per event by a licensed contractor. This total includes an assumed 35,100 pounds at the Watt Road zone and 52,800 pounds at the railroad track zone per injection event. The higher mass at the downgradient zone is considered necessary to overcome the naturally aerobic conditions present at this location. The mass estimate was determined using proprietary software from Regenesis and a printout is provided in Appendix D.1. It is estimated that one injection would be necessary every 3 years over a 16-year period of performance. Costing for this alternative is located in Appendix D, Table D-2.

4.5.1.2 Alternative 3.B: Addition of HRC-X and ORC

This scenario would involve treating the more anaerobic zone near Watt Road with HRC-X and the more aerobic portion of the aquifer west of the Southern Pacific Railroad tracks with ORC. One HRC-X injection zone would be placed along the width of the paleochannel on the west side of Watt Road, as shown on Figure 4-1. The injection well barrier at Watt Road would utilize the three existing wells from the treatability study, with the installation of an estimated 12 additional injection wells using sonic drilling technology for the purpose of facilitating HRC-X injection into the saturated zone.

Based on geochemical data for the area downgradient of the Southern Pacific Railroad Tracks, subsurface aquifer conditions appear conducive to oxidative treatment. The IRZ in this area would consist of injecting ORC slurry along the width of the paleochannel on the west side of the Southern Pacific Railroad Tracks, as shown on Figure 4-2. Because *in-situ* oxidation has not been identified as an effective remedy for Site 13C, an initial bench scale pilot test would be performed before full-scale implementation. Using a spacing of 10 feet, an estimated 15 injection borings would be drilled using sonic drilling technology. The ORC slurry would be injected into the saturated zone in this area. Injection wells are not specified for ORC since it forms an insoluble oxide and may lead to well clogging after injection. A total of 35,100 pounds of HRC-X and 1,575 pounds of ORC product are assumed to be injected by a licensed contractor. The basis for the mass estimate was determined using proprietary software from Regenesis, and the spreadsheet is provided in Appendix D. An additional 5 monitoring wells would be installed to permit monitoring of aquifer conditions in the vicinity of the HRC-X and ORC injection locations. It is estimated that the injection of HRC-X would occur every 3 years and the injection of ORC would occur every 2 years. Costing for this alternative is located in Appendix D.2 and Table D-3.

4.5.1.3 Alternative 3.C: Diffusive Oxygen and Hydrogen Emitters (iSOC)

This scenario would involve treating the aquifer with 99.6 percent pure oxygen gas and hydrogen gas, which would be delivered via diffusive gas emitters. For Site 13C, this system would deliver dissolved oxygen for aerobic biodegradation (aerobic respiration) downgradient of the Southern Pacific Railroad tracks, where the subsurface aquifer conditions appear conducive to oxidative treatment. Dissolved hydrogen for anaerobic biodegradation (e.g., reductive dechlorination of chlorinated solvents) would be applied along the width of the paleochannel on the west side of Watt Road

The iSOC is a microporous, hollow-fiber membrane mass transfer device that is inserted into existing groundwater wells. The hollow fiber material is hydrophobic and provides the large surface area necessary to accomplish mass transfer. The unit is set into an existing well and pressurized to just equal the hydrostatic pressure, such that only a diffusive (i.e., not an advective) gradient is established. This approach results in supersaturation of the water column within the well with the delivered gas. Natural groundwater flow is relied upon to advectively carry the gas-enriched groundwater downgradient to a targeted treatment zone. Because of the reliance upon natural groundwater flow, a closer well spacing is generally required.

Costs associated with this technology would include procurement of the individual delivery systems, in addition to periodic monitoring and replacement of high-pressure gas cylinders. Costing for this alternative is located in Appendix D.3, Table D-4.

4.5.1.4 Alternative 3.D: Addition of Soybean Oil

This scenario involves the application of food grade emulsified soybean oil (ESO), via injection wells into the aquifer. Naturally occurring microorganisms would utilize the soybean oil as a carbon and energy source to produce hydrogen necessary for reductive dechlorination. A diluted soybean oil emulsion has low viscosity, which allows a greater volume of substrate to be applied in a shorter period of time, thus increasing the radius of influence. Soybean oil has been successfully applied as a reactive barrier at other sites. This alternative may not be effective at the downgradient IRZ due to subsurface aerobic conditions. Because ambient groundwater conditions in the downgradient aquifer are semi-aerobic, this alternative will require large quantities of ESO to be injected, and may require a longer total treatment duration.

If implemented, it is expected that reinjection of soybean oil would occur every 4 years. One soybean oil injection zone would be placed along the width of the paleochannel on the west side of Watt Road, as shown on Figure 4-1. The injection well barrier would utilize the 3 existing wells from the treatability study, and the 12 additional injection wells proposed in this EE/CA. An injection well would be completed at each location for the purpose of facilitating soybean oil injection into the saturated zone. Another soybean oil injection zone consisting of 15 wells spaced at 10-foot intervals would be placed in the downgradient location, along the width of the paleochannel on the west side of the Southern Pacific Railroad tracks, as shown on Figure 4-2. It should be noted Alternative 3.D may not be effective due to semi-aerobic subsurface conditions. An additional 5 monitoring wells would be installed to support process monitoring over the duration of the removal action program. Costing for this alternative is located in Appendix D.4 and Table D-5.

4.5.1.5 Alternative 3.E: Diffusive Oxygen Emitters and Soybean Oil

This scenario would involve treating the aquifer with a dual technology approach. The Watt Road (Figure 4-1) area would be treated with soybean oil via injection wells into the aquifer. Naturally occurring microorganisms would utilize the soybean oil as a carbon and energy source for reductive dechlorination. A diluted soybean oil emulsion has low viscosity, which allows a greater volume of substrate to be applied in a shorter period of time, thus increasing the radius of influence. Soybean oil has been successfully applied as a reactive barrier. It is expected that reinjection of soybean oil would occur every 4 years. The injection well barrier would utilize the 3 existing wells from the treatability study, and up to 12 additional injection wells. The injection wells would be installed in separate drilling phases. The first phase of drilling would provide a total of six new injection wells, three injection wells spaced at 20-foot intervals on each side of existing injection wells 14-INJ-5/6 and 14-INJ-1/2. Soybean oil injection would then proceed within this initial injection well field of 9 wells. Based on subsequent review of monitoring data, if additional injection wells were found to be necessary to complete the integrity of the barrier, installation of the remaining 6 wells would ensue followed by injection of soybean oil into the newly installed wells. An injection well would be completed at each location to facilitate injection of ESO into the saturated zone.

The downgradient Southern Pacific Railroad tracks location would be treated with 99.6 percent purity oxygen gas delivered via diffusive gas emitters. For Site 13C, this system would deliver dissolved oxygen for aerobic biodegradation (aerobic respiration), where the subsurface aquifer conditions appear conducive to aerobic treatment. The iSOC is a microporous, hollow-fiber membrane mass transfer device that is inserted into existing groundwater wells. The hollow-fiber material is hydrophobic and provides the large surface area necessary to accomplish mass transfer. The unit is set into an existing well and pressurized to just equal the hydrostatic pressure such that only a diffusive (i.e., not an advective) gradient is established. This approach results in supersaturation of the water column within the well with the delivered gas. Natural groundwater flow is relied upon to advectively carry the gas-enriched groundwater downgradient to a targeted treatment zone. Costs associated with this technology include procurement of the individual delivery systems, in addition to periodic monitoring and replacement of high-pressure gas cylinders.

An additional 5 monitoring wells would be installed to support process monitoring over the duration of the removal action program. Costing for this alternative is located in Table D-6.

4.5.2 Comparison of *In-Situ* Bioremediation Technologies

Five *in-situ* bioremediation approaches (Appendix D) were screened according to their perceived effectiveness in remediation of *trans*-1,2-DCE, *cis*-1,2-DCE, and vinyl chloride. All options are expected to achieve the objectives of the IRA for Site 13C, though implementation differs among the technology types, and this will affect estimated costs. A ranking of the five approaches with respect to cost, implementability, and duration is provided in Table 4-2. Diffusive oxygen and hydrogen emitters (Alternative 3C) require relatively frequent adjustment of delivery pressures and the change-out of gas cylinders at the site. This would require field staff to visit the site multiple times each quarter; presenting a modest increase in field labor, which would be offset by lower capital cost. Although oxygen emitter technologies have been shown to be successful at Vandenberg AFB (i.e., IRP Site 60), hydrogen gas introduction remains a relatively new technology, and its record of successful implementation is somewhat limited compared to that for treatment technologies.

Compared to diffusion systems, injected treatments such as HRC-X, ORC, and soybean oil require less frequent O&M oversight. HRC-X, ORC, and soybean oil technologies would require periodic injection: 3 years for HRC-X, 2 years for ORC, and 4 years for soybean oil. For injection, HRC-X must be heated to decrease its viscosity. Based on vendor estimates, approximately 1,200 pounds of HRC-X could be injected in one field day. Therefore, since it is estimated that approximately 87,900 pounds of HRC-X would be necessary for Alternative 3.A, approximately 74 days would be required for injection. ORC can be injected at a rate of 1,800 pounds per day. It is expected that for Alternative 3.B, injection of both the HRC-X and ORC would require 30 days. Since ORC forms an insoluble oxide after releasing oxygen to the subsurface, it may clog wells after one or more injections. Therefore, costs for ORC injection include drilling to depth to facilitate injection into open borings.

Table 4-2

***In-Situ* Bioremediation Ranking Summary**

In-Situ Bioremediation Alternatives	Cost	Implementability	Project Duration	Total Rank
Alternative 3.A: HRC-X	0	3	3	6
Alternative 3.B: HRC-X and ORC	1	3	3	7
Alternative 3.C: iSOC Installation	2	3	3	8
Alternative 3.D: Soybean Oil Injection	2	3	3	8
Alternative 3.E: iSOC and Soybean Oil	3	3	3	9

Notes:
1. The number 0 indicates the least desirable rank; 3 denotes the highest
2. Costs based on present worth analysis are summarized in Table 4-1 and detailed in Appendix D
3. Project duration (period of performance) estimated to be 16 years.

iSOC – *In-situ* Submerged Oxygen Curtain
IRA - interim removal action
HRC - Hydrogen Release Compound
HRC-X - Hydrogen Release Compound, Extended Release Formula
ORC - Oxygen Release Compound

Of the three liquid substrates evaluated, soybean oil is considered the easiest to inject. It provides a long-lasting hydrogen source, and, due to its low viscosity, it can be injected at a rate of 1,800 pounds per day.

Based on the dose of 4,848 pounds of soybean oil required at both sites, it is estimated that 3 days will be required for injection. Soybean oil will disperse in the aquifer and is not expected to cause fouling of any of the injection wells, allowing them to be used again. Soybean oil has the longest time between injections: 4 years. In addition, soybean oil yields an estimated 14 hydrogen ions, compared to 12 for HRC-X, and its cost may be as much as an order of magnitude lower than the cost of HRC-X. Based on the evaluation of effectiveness, implementability, and cost, soybean oil ranks as the most appropriate injection substrate for use in the Site 13C IRA.

Tetra Tech completed a treatability study that was initiated in fall 2003 (Appendix A). The objective of this study was to provide sufficient data on the use of a hydrogen release compound, HRC-X, to facilitate anaerobic degradation of *trans*-1,2-DCE, *cis*-1,2-DCE, and vinyl chloride in groundwater near Watt Road. As discussed in Section 2.2.4 and Appendix A, the treatability study proved to be successful in enhancing anaerobic degradation of *cis*-1,2-DCE completely through the ethene. Based on acceptance of use of this technology at Site 13C, previous research has shown that both soybean oil and HRC-X are appropriate substrates for contaminant degradation. Since soybean oil produces more hydrogen ions than HRC-X, is less expensive, and is easier to inject, Tetra Tech recommends soybean oil as the preferred substrate for enhancement of *in-situ* anaerobic biodegradation at Watt Road. Since HRC-X and soybean oil are similar technologies, Tetra Tech does not anticipate a negative interaction between the HRC-X injected for the treatability study and soybean oil recommended for injection in the IRA.

At the western margin of the Southern Pacific Railroad tracks, groundwater conditions range from slightly anaerobic near the bottom of the paleochannel (well 14-MW-6) to slightly aerobic in the upper aquifer (well 14-MW-7). Use of an oxygenation technology in this area of the paleochannel is favored over a reduction approach. Based on comparison of costs to inject ORC via borings versus introducing pure oxygen via iSOC diffusive emitters into the well array, capital and long-term costs for the iSOC approach would be much lower. Based on the selection criteria discussed herein, Alternative 3.E, which combines an electron donor (i.e., soybean oil) approach to promote reductive dechlorination at Watt Road, with an electron acceptor (i.e., oxygen) to promote aerobic degradation in the downgradient paleochannel is the selected alternative. The proposed schedule scope methods and strategy of deployment of Alternative 3 are presented in Section 5.

In order to prevent use of Site 13C groundwater containing chemicals above drinking water standards as a potable water source before or during remediation, institutional controls will be necessary in accordance with California Health and Safety Code Sections 25260 and 25222.1. The final remedy for Site 13C will be documented in the Feasibility Study/Remedial Action Plan.

5.0 RECOMMENDED INTERIM REMOVAL ACTION

5.1 SCOPE

The recommended removal action scope incorporates a dual-technology remediation system. At Watt Road, injection wells will be installed and soybean oil will be injected into up to 15 locations consisting of 3 existing wells and 12 new injection wells, along the width of the paleochannel to create an *in-situ* reactive zone for reductive dechlorination of *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride. At the Southern Pacific Railroad tracks, 15 additional wells will be installed, and diffusive oxygen emitters will be installed in each well to facilitate aerobic biodegradation.

Following are the specific recommended activities:

- Install groundwater injection/emitter wells near Watt Road and the Southern Pacific Railroad tracks
- Install groundwater monitoring wells to accommodate monitoring of the IRA near Watt Road and the Southern Pacific Railroad Tracks. Survey and develop the wells
- Properly dispose of all investigation-derived waste.
- Conduct baseline monitoring.
- Inject soybean oil in up to 12 wells at the Watt Road location
- Install up to 15 diffusive oxygen emitters at the Southern Pacific Railroad track location.
- Conduct quarterly post-injection monitoring.
- Inject soybean oil every 4 years, or as needed.
- Replace oxygen cylinders every 2 months, or as needed.
- Operate soybean oil system for up to 16 years.
- Operate diffusive oxygen emitter system for up to 6 years.
- Prepare and submit progress reports, as required.

5.2 PRELIMINARY SCHEDULE

The tentative schedule for this removal action is shown in Table 5-1. This schedule is contingent on the following factors:

- Obtaining timely regulatory approval of the EE/CA;
- Adequate funding and contracting availability; and
- Achievement of removal action goals within the anticipated period of performance.

The regulatory agencies will be provided an opportunity to review and approve the Draft IRA Work Plan prior to its inclusion in the Final EE/CA. All field work will comply with the *Handbook to Support the IRP Statements of Work, Volume 1, Remedial Investigation/Feasibility Study* (U.S. Air Force 1993) and the Basewide Sampling and Analysis Plan (U.S. Air Force 2003).

6.0 REFERENCES

California Department of Toxic Substances Control (DTSC)

1992 *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities*. Office of the Science Advisor, State of California Department of Toxic Substances Control, Sacramento, CA.

California Department of Toxic Substances Control (DTSC)

1999 *Preliminary Endangerment Assessment Guidance Manual* (PEA Guidance Manual). California Environmental Protection Agency, Sacramento, California. Second Printing.

California Department of Toxic Substances Control (DTSC)

2000 Draft memorandum: guidance for the dermal exposure pathway. January.

Coulombe, H.N., and C.F. Cooper (eds.)

1976 *Ecological Assessment of Vandenberg Air Force Base, California, Volume I. Evaluation and Recommendations 1974/75. Final Report*. Prepared by Center for Regional Environmental Studies, San Diego State University for U.S. Air Force, Headquarters for Space and Missile Systems Organization. Report No. AFCEC-TR-76-15.

Mayer, K.E., and W.F. Laudenslayer

1988 *A Guide to Wildlife Habitats of California*. California Department of Forestry and Fire Protection.

Nature Conservancy, The

1991 *Fish and Wildlife Management Plan for Vandenberg Air Force Base*. Revision Number 3 for Plan Period August 1991 to August 1997. Prepared for Vandenberg Air Force Base.

Naval Facilities Engineering Service Center (NFESC)

2004 Naval Facilities Engineering Service Center Remediation Topic Group Webpage: http://enviro.nfesc.navy.mil/erb/restoration/technologies/remed/main.htm.

O'Brien and Gere Engineers, Inc. (O'Brien and Gere.)

1995 Innovative Engineering Technologies for Hazardous Waste Remediation, Van Nostrand Reinhold, New York.

Schmalzer, P.A., D.A. Hickson, and C.R. Hinkle

1988 *Vegetation Studies on Vandenberg Air Force Base, California*. NASA Technical Memorandum 100985. National Aeronautics and Space Administration, Biomedical Operations and Research Office. John F. Kennedy Space Center, Florida.

State Water Resources Control Board (SWRCB)

1994 *Application of State Water Board Resolution 68-16 to Cleanup of Contaminated Groundwater*. February.

Tetra Tech, Inc. (Tetra Tech)

2003 *30th Space Wing Vandenberg AFB Peer Review Pre-Brief Package, 26-27 August 2003, HQ AFSPC Peer Review Meeting, Colorado Springs, CO*.

Tetra Tech, Inc. (Tetra Tech)

2004a *Draft Remedial Investigation/Feasibility Study for Site 13 Cluster (ABRES-A Launch Complex, ABRES-A Lake, and Missile Silo 395-B), Operable Unit 4, Vandenberg AFB, California.* In preparation for 30 CES/CEV, Installation Restoration Program, Vandenberg Air Force Base, California, and Headquarters Air Force Space Command (HQ ADSPACECOM), Peterson Air Force Base, Colorado. January.

Tetra Tech, Inc. (Tetra Tech)

2004b *Field Modification Report, Site 13C, Surface Water and Sediment Sampling.* 02 September.

U.S. Air Force

1993 *Handbook for the Installation Restoration Program (IRP) Remedial Investigations and Feasibility Studies (RI/FS).* Headquarters, Air Force Center for Environmental Excellence (AFCEE), Environmental Services Directorate, Brooks Air Force Base, Texas. September.

U.S. Air Force

2003 *Basewide Sampling and Analysis Plan Final.* Prepared for 30 CES/CEV, Installation Restoration Program, Vandenberg Air Force Base, California, and Headquarters Air Force Space Command, Peterson Air Force Base, Colorado. Prepared by Tetra Tech, Inc. September.

U.S. Environmental Protection Agency (U.S. EPA)

1993 *Guidance for Conducting Non-Time-Critical Removal Actions Under CERCLA.* EPA/540-R-93-057, Publication 9360.0-32, PB93-963402

U.S. Environmental Protection Agency (U.S. EPA)

1988 *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* Office of Emergency and Remedial Response, Washington, DC. December. EPA-540/6-89/004.

U.S. Environmental Protection Agency (U.S. EPA)

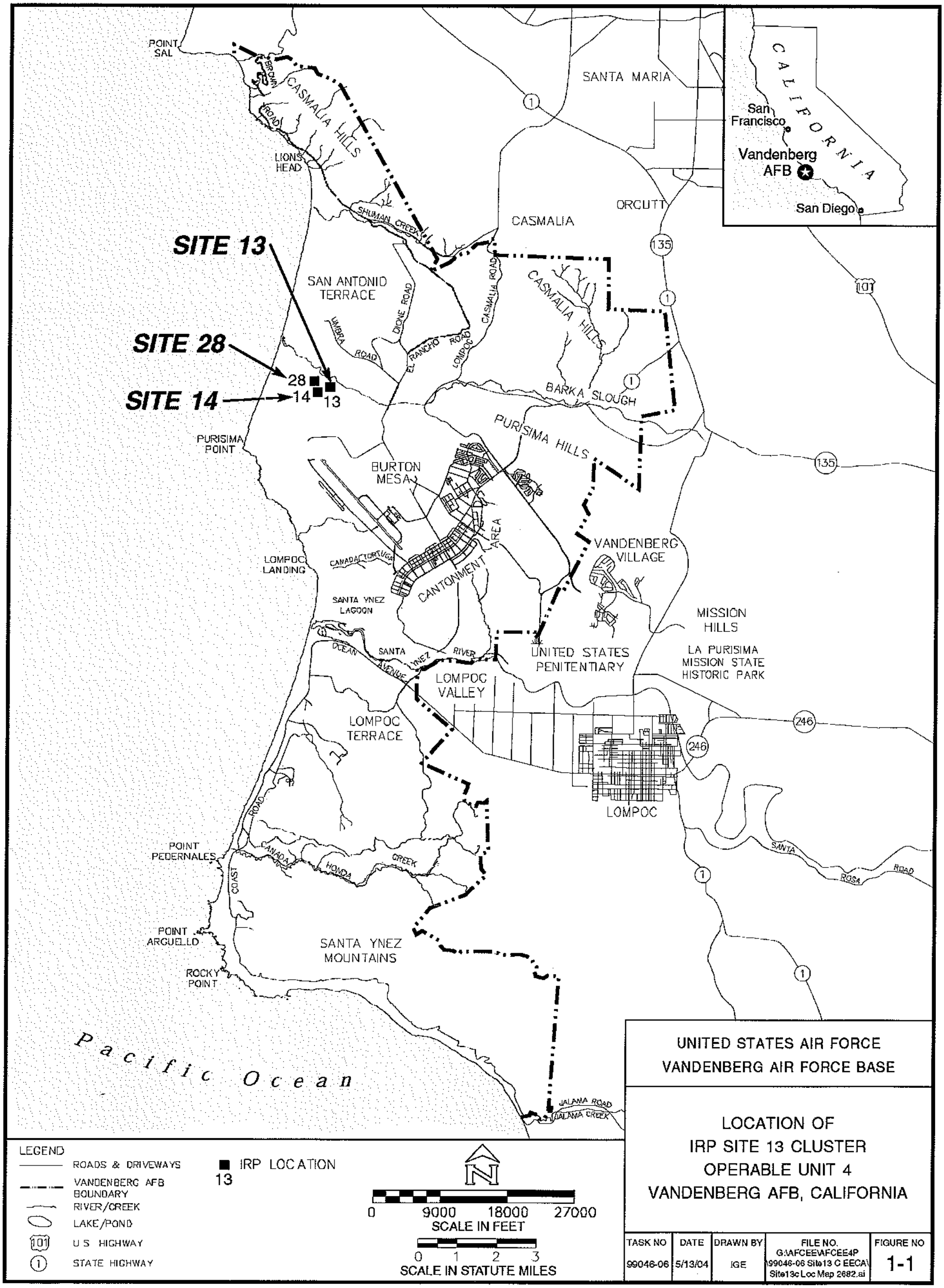
1989 *Risk Assessment Guidance for Superfund (RAGS). Human Health Evaluation Manual Part A.* Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002.

7.0 ACRONYMS AND ABBREVIATIONS

13C	13 Cluster
ABRES-A	Advanced Ballistic Re-Entry Systems-A
AFB	Air Force Base
AOC	area of concern
ARAR	Applicable or Relevant and Appropriate Requirements
Battelle	Battelle Corporation
BGMP	Basewide Groundwater Monitoring Program
bgs	below ground surface
Cal/EPA	California Environmental Protection Agency
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COPC	chemical of potential concern
CSM	conceptual site model
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DTSC	Department of Toxic Substances Control
ESO	emulsified soybean oil
EE/CA	engineering evaluation/cost analysis
ERA	Environmental Risk Assessment
FS	Feasibility Study
feet/day	feet per day
HI	Hazard Index
HQ	Hazard Quotient
HRC	Hydrogen Release Compound
HRC-X	Hydrogen Release Compound, Extended Release Formula
IRA	interim removal action
IRP	Installation Restoration Program
IRZ	*in-situ* reactive zone
ISCO	*in-situ* chemical oxidation
iSOC	*In-situ* Submerged Oxygen Curtain
JEG	Jacobs Engineering Group
MCL	maximum contaminant level
µg/L	micrograms per liter
mg/L	milligrams per liter

MNA	Monitored Natural Attenuation
MT3D	Modular Three Dimensional Transport Model
NFESC	Naval Facilities Engineering Services Center
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
O&M	operation and maintenance
ORC	Oxygen Release Compound
ORP	oxidation/reduction potential
RA-C	Remedial Action-Construction
RCRA	Resource Conservation and Recovery Act
Regenesis	Regenesis, Inc.
Reynolds	Reynolds, Smith, and Hill, Inc.
RI	Remedial Investigation
RP-1	Rocket Propellant-1
RT3D	Multi-Species Reactive Transport Simulation Software
RWQCB	Regional Water Quality Control Board
SAIC	Science Applications International Corporation
SWRCB	State Water Resources Control Board
Tetra Tech	Tetra Tech, Inc.
TCE	trichloroethene
TCLP	Toxics Characteristics Leaching Procedure
UST	underground storage tank
U.S. EPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	volatile organic compound

FIGURES



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

LOCATION OF
IRP SITE 13 CLUSTER
OPERABLE UNIT 4
VANDENBERG AFB, CALIFORNIA

TASK NO	DATE	DRAWN BY	FILE NO.	FIGURE NO
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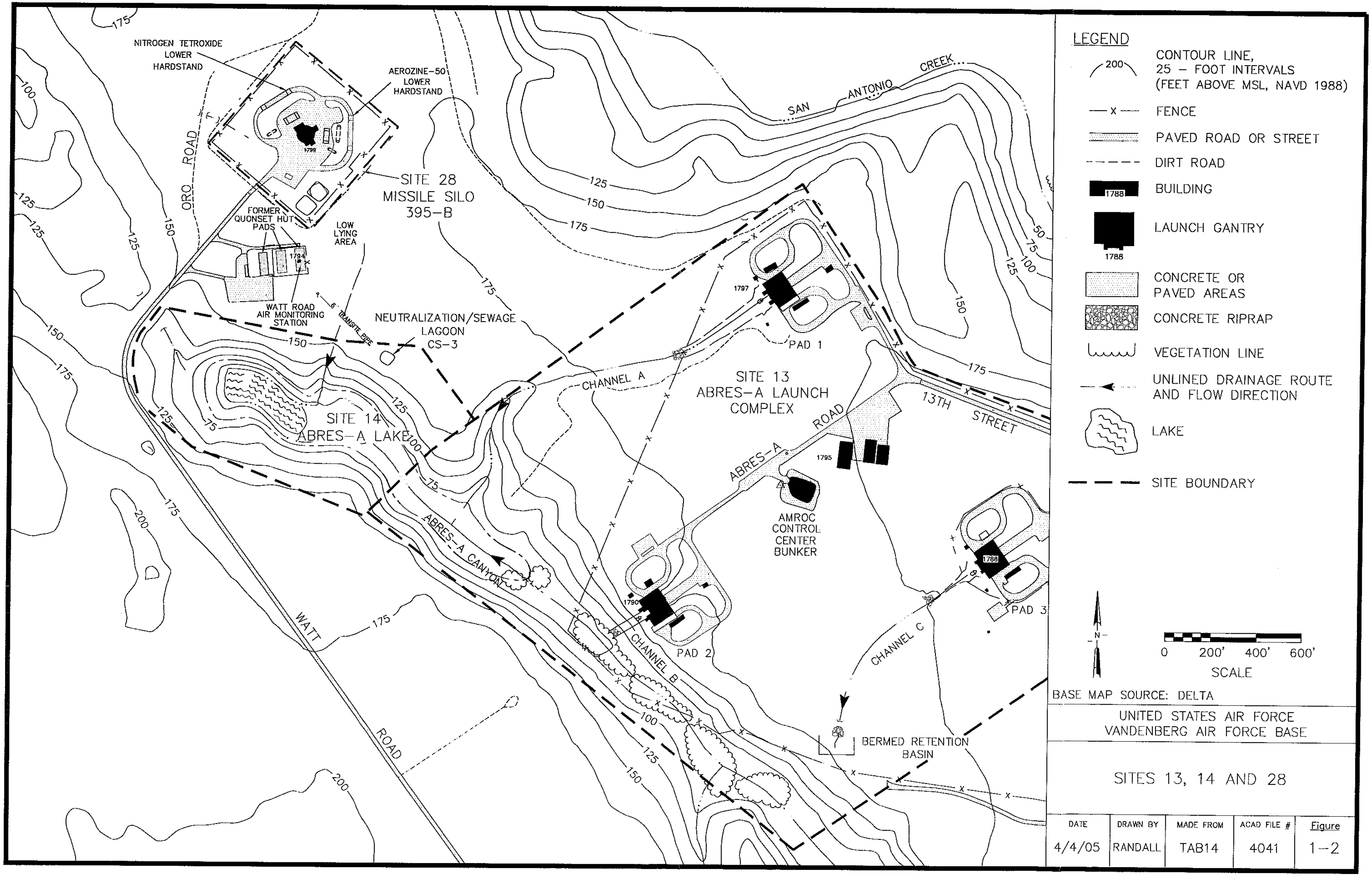
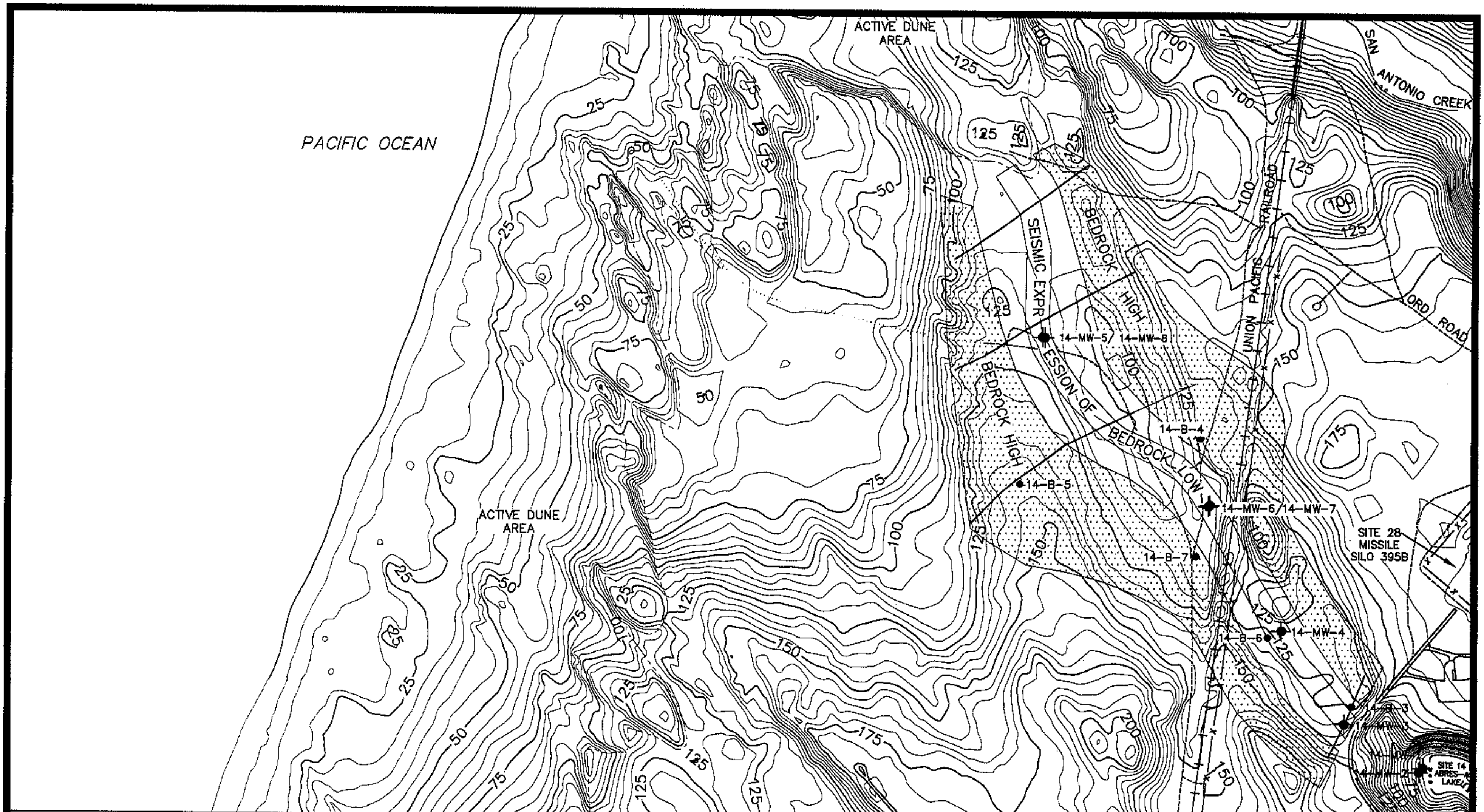

NITROGEN TETROXIDE LOWER HARDSTAND
AEROZINE-50 LOWER HARDSTAND
SITE 28 MISSILE SILO 395-B
FORMER QUONSET HUT PADS
LOW LYING AREA
WATT ROAD AIR MONITORING STATION
TRANSITE PIPE
NEUTRALIZATION/SEWAGE LAGOON CS-3
ORO ROAD
SAN ANTONIO CREEK
CHANNEL A
SITE 13 ABRES-A LAUNCH COMPLEX
SITE 14 ABRES-A LAKE
PAD 1
PAD 2
PAD 3
13TH STREET
ABRES-A ROAD
AMROC CONTROL CENTER BUNKER
ABRES-A CANYON
CHANNEL B
CHANNEL C
BERMED RETENTION BASIN
WATT ROAD
1797
1798
1794
1795
1790
1788
LEGEND
CONTOUR LINE, 25 – FOOT INTERVALS (FEET ABOVE MSL, NAVD 1988)
FENCE
PAVED ROAD OR STREET
DIRT ROAD
BUILDING
LAUNCH GANTRY
CONCRETE OR PAVED AREAS
CONCRETE RIPRAP
VEGETATION LINE
UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
LAKE
SITE BOUNDARY
N
0 200' 400' 600'
SCALE
BASE MAP SOURCE: DELTA
UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE
SITES 13, 14 AND 28
DATE 4/4/05
DRAWN BY RANDALL
MADE FROM TAB14
ACAD FILE # 4041
Figure 1-2



LEGEND

CONTOUR LINE, 5 – FOOT INTERVALS (FEET ABOVE MSL, NAVD 1988)

RAILROAD

FENCE

PAVED ROAD OR STREET

DIRT ROAD

VEGETATION LINE

UNLINED DRAINAGE ROUTE AND FLOW DIRECTION

SAND DUNE

14-MW-1 GROUNDWATER MONITORING WELL

14-B-3 SOIL BORING

LINE OF GEOPHYSICAL SURVEY TRANSECT

0 375' 750'

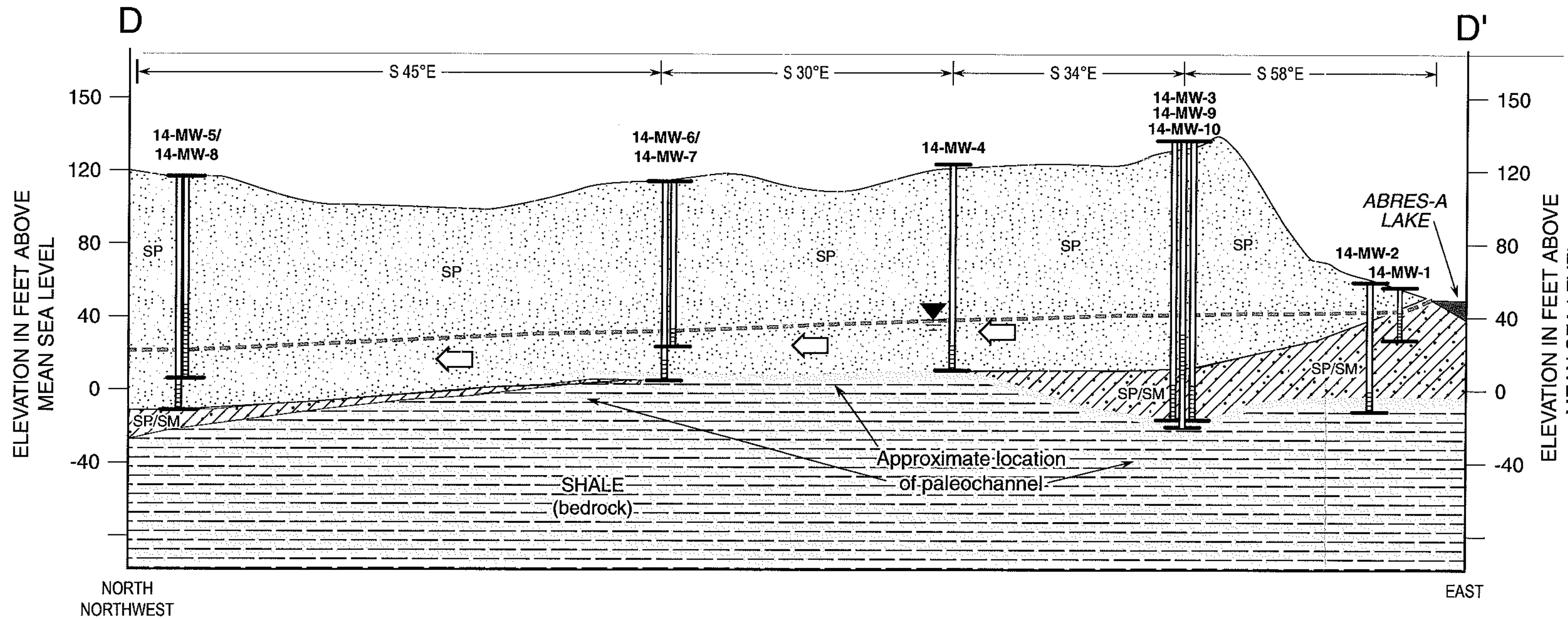
SCALE

UNITED STATES AIR FORCE

VANDENBERG AIR FORCE BASE

SITE 14
GEOPHYSICAL SURVEY
TRANSECTS AND INTERPRETATION

DATE	DRAWN BY	MADE FROM	ACAD FILE #	Figure
4/4/05	RANDALL	TAB14	4042	2-1

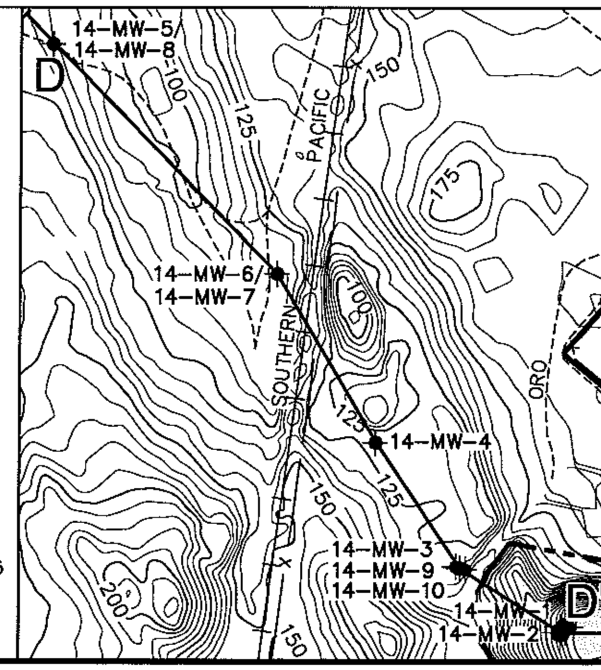


LEGEND

- SP — Poorly Graded Sand
- Shale (bedrock)
- SP/SM — Fine-Grained Sand (with minor silt)
- Approximate Extent of Dissolved Contaminant Plume
- **14-MW-5** Monitoring Well Location
  - Total Depth
  - Screen Interval
- Groundwater Level (Winter 2004)
- Groundwater Flow Direction

0 125 450 575

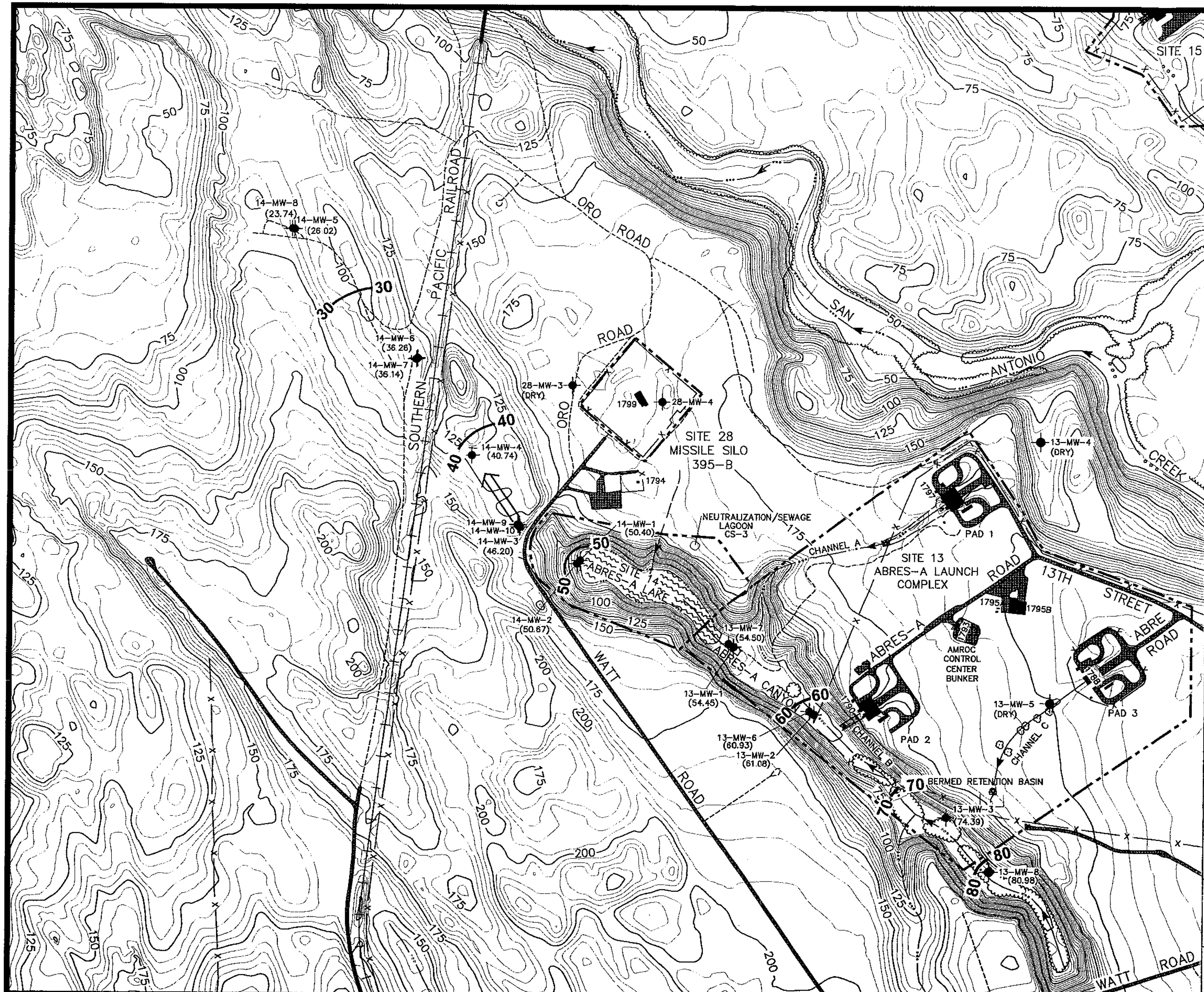
HORIZONTAL SCALE: 1" = 450'
VERTICAL SCALE: 1" = 65'



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

LITHOLOGIC
CROSS-SECTION D-D' ALONG AXIS
OF ABRES-A CANYON AND
PALEOCHANNEL

TC NO	DATE	DRAWN BY	DWG NO	FIGURE NO
99046-06	5/20/05	IGE	4888	2-2



LEGEND

- CONTOUR OF GROUND SURFACE ELEVATION IN FEET ABOVE MSL (25-FOOT INTERVALS) (NAVD 1988)
- RAILROAD
- FENCE
- PAVED ROAD OR STREET
- DIRT ROAD
- TRAIL
- BUILDING
- CONCRETE OR PAVED AREAS
- LAKE
- VEGETATION LINE
- UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
- 80 —— 80 GROUNDWATER ELEVATION CONTOUR APPROXIMATED BY LINEAR INTERPOLATION (DASHED WHERE INFERRED)
- LAKE SURFACE ELEVATION CONTOUR
- INFERRED GROUNDWATER FLOW DIRECTION
- SITE BOUNDARY
- 13-MW-2 (61.08) GROUNDWATER MONITORING WELL WITH GROUNDWATER ELEVATION

NOTE: GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL AS MEASURED IN JULY 2003

N

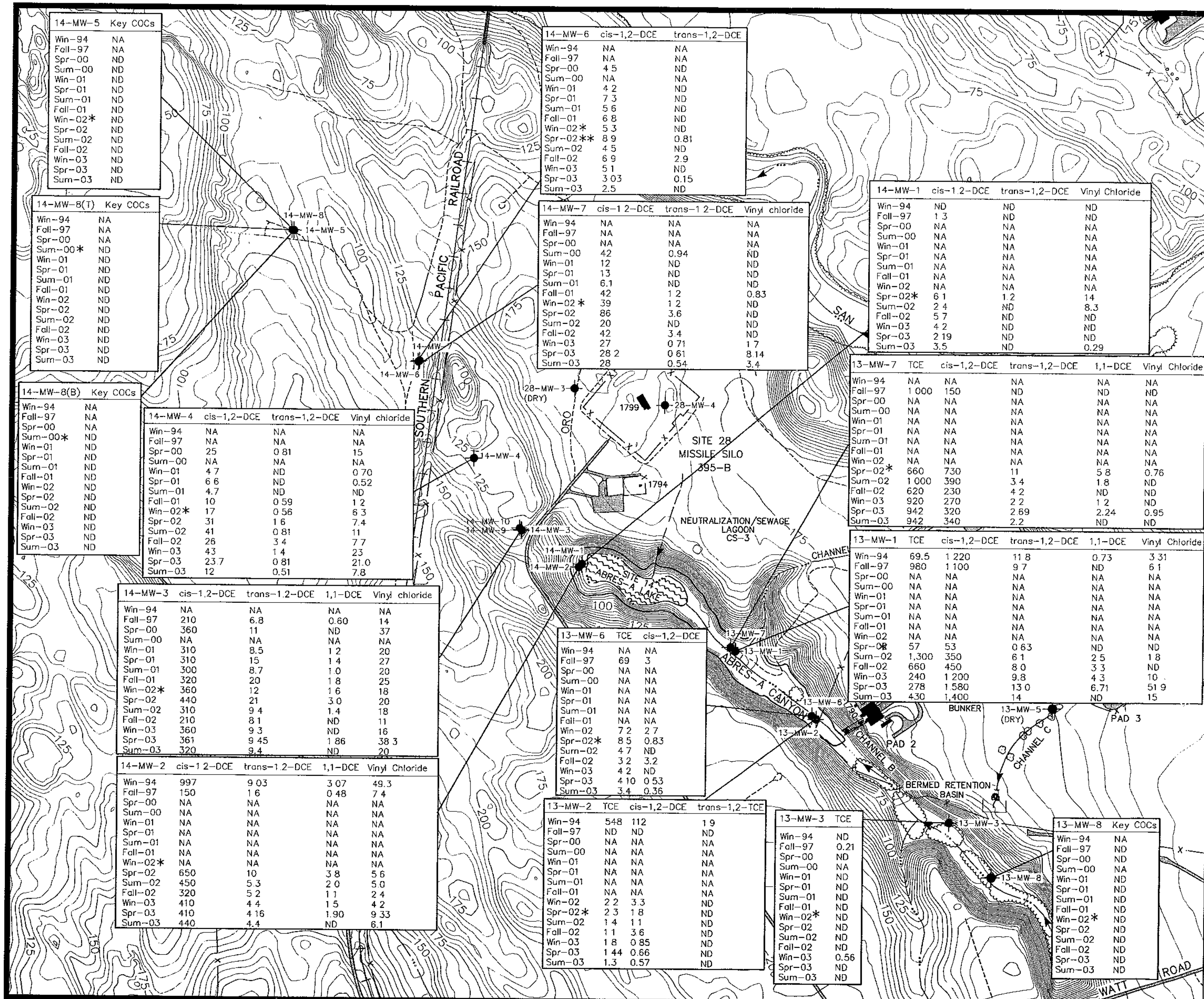
0 350' 700' 1050'
SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
ABRES-A LAUNCH COMPLEX AND ABRES-A LAKE
SITE PLAN AND GROUNDWATER CONTOUR MAP
SUMMER 2003

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO.	DATE	DRAWN BY	MADE FROM	ACAD FILE #	Figure
99046-06	10/11/04	PRICHARD	TAB14 TAB15	4039	2-3



14-MW-5	Key COCs
Win-94	NA
Fall-97	NA
Spr-00	ND
Sum-00	ND
Win-01	ND
Spr-01	ND
Sum-01	ND
Fall-01	ND
Win-02*	ND
Spr-02	ND
Sum-02	ND
Fall-02	ND
Win-03	ND
Spr-03	ND
Sum-03	ND

14-MW-8(T)	Key COCs
Win-94	NA
Fall-97	NA
Spr-00	NA
Sum-00*	ND
Win-01	ND
Spr-01	ND
Sum-01	ND
Fall-01	ND
Win-02	ND
Spr-02	ND
Sum-02	ND
Fall-02	ND
Win-03	ND
Spr-03	ND
Sum-03	ND

14-MW-8(B)	Key COCs
Win-94	NA
Fall-97	NA
Spr-00	NA
Sum-00*	ND
Win-01	ND
Spr-01	ND
Sum-01	ND
Fall-01	ND
Win-02	ND
Spr-02	ND
Sum-02	ND
Fall-02	ND
Win-03	ND
Spr-03	ND
Sum-03	ND

14-MW-6	cis-1,2-DCE	trans-1,2-DCE
Win-94	NA	NA
Fall-97	NA	NA
Spr-00	4 5	ND
Sum-00	NA	NA
Win-01	4 2	ND
Spr-01	7 3	ND
Sum-01	5 6	ND
Fall-01	6 8	ND
Win-02*	5 3	ND
Spr-02**	8 9	0.81
Sum-02	4 5	ND
Fall-02	6 9	2.9
Win-03	5 1	ND
Spr-03	3 03	0.15
Sum-03	2.5	ND

14-MW-7	cis-1 2-DCE	trans-1 2-DCE	Vinyl chloride
Win-94	NA	NA	NA
Fall-97	NA	NA	NA
Spr-00	NA	NA	NA
Sum-00	42	0.94	ND
Win-01	12	ND	ND
Spr-01	13	ND	ND
Sum-01	6.1	ND	ND
Fall-01	42	1 2	0.83
Win-02*	39	1 2	ND
Spr-02	86	3.6	ND
Sum-02	20	ND	ND
Fall-02	42	3.4	ND
Win-03	27	0 71	1 7
Spr-03	28 2	0 61	8.14
Sum-03	28	0.54	3.4

14-MW-1	cis-1.2-DCE	trans-1,2-DCE	Vinyl Chloride
Win-94	ND	ND	ND
Fall-97	1 3	ND	ND
Spr-00	NA	NA	NA
Sum-00	NA	NA	NA
Win-01	NA	NA	NA
Spr-01	NA	NA	NA
Sum-01	NA	NA	NA
Fall-01	NA	NA	NA
Win-02	NA	NA	NA
Spr-02*	6 1	1.2	14
Sum-02	2 4	ND	8.3
Fall-02	5 7	ND	ND
Win-03	4 2	ND	ND
Spr-03	2 19	ND	ND
Sum-03	3.5	ND	0.29

14-MW-4	cis-1,2-DCE	trans-1,2-DCE	Vinyl chloride
Win-94	NA	NA	NA
Fall-97	NA	NA	NA
Spr-00	25	0 81	15
Sum-00	NA	NA	NA
Win-01	4 7	ND	0 70
Spr-01	6 6	ND	0.52
Sum-01	4.7	ND	ND
Fall-01	10	0 59	1 2
Win-02*	17	0 56	6 3
Spr-02	31	1 6	7.4
Sum-02	41	0 81	11
Fall-02	26	3 4	7 7
Win-03	43	1 4	23
Spr-03	23.7	0 81	21.0
Sum-03	12	0.51	7.8

14-MW-3	cis-1,2-DCE	trans-1.2-DCE	1,1-DCE	Vinyl chloride
Win-94	NA	NA	NA	NA
Fall-97	210	6.8	0.60	14
Spr-00	360	11	ND	37
Sum-00	NA	NA	NA	NA
Win-01	310	8.5	1 2	20
Spr-01	310	15	1 4	27
Sum-01	300	8.7	1.0	20
Fall-01	320	20	1 8	25
Win-02*	360	12	1 6	18
Spr-02	440	21	3.0	20
Sum-02	310	9 4	1.4	18
Fall-02	210	8 1	ND	11
Win-03	360	9 3	ND	16
Spr-03	361	9 45	1 86	38 3
Sum-03	320	9.4	ND	20

14-MW-2	cis-1 2-DCE	trans-1.2-DCE	1,1-DCE	Vinyl Chloride
Win-94	997	9 03	3 07	49.3
Fall-97	150	1 6	0 48	7 4
Spr-00	NA	NA	NA	NA
Sum-00	NA	NA	NA	NA
Win-01	NA	NA	NA	NA
Spr-01	NA	NA	NA	NA
Sum-01	NA	NA	NA	NA
Fall-01	NA	NA	NA	NA
Win-02*	NA	NA	NA	NA
Spr-02	650	10	3 8	5 6
Sum-02	450	5.3	2 0	5.0
Fall-02	320	5 2	1 1	2 4
Win-03	410	4 4	1 5	4 2
Spr-03	410	4 16	1.90	9 33
Sum-03	440	4.4	ND	6.1

13-MW-7	TCE	cis-1,2-DCE	trans-1,2-DCE	1,1-DCE	Vinyl Chloride
Win-94	NA	NA	NA	NA	NA
Fall-97	1 000	150	ND	ND	ND
Spr-00	NA	NA	NA	NA	NA
Sum-00	NA	NA	NA	NA	NA
Win-01	NA	NA	NA	NA	NA
Spr-01	NA	NA	NA	NA	NA
Sum-01	NA	NA	NA	NA	NA
Fall-01	NA	NA	NA	NA	NA
Win-02	NA	NA	NA	NA	NA
Spr-02*	660	730	11	5 8	0.76
Sum-02	1 000	390	3.4	1.8	ND
Fall-02	620	230	4 2	ND	ND
Win-03	920	270	2 2	1 2	ND
Spr-03	942	320	2.69	2.24	0.95
Sum-03	942	340	2.2	ND	ND

13-MW-1	TCE	cis-1,2-DCE	trans-1,2-DCE	1,1-DCE	Vinyl Chloride
Win-94	69.5	1 220	11 8	0.73	3 31
Fall-97	980	1 100	9 7	ND	6 1
Spr-00	NA	NA	NA	NA	NA
Sum-00	NA	NA	NA	NA	NA
Win-01	NA	NA	NA	NA	NA
Spr-01	NA	NA	NA	NA	NA
Sum-01	NA	NA	NA	NA	NA
Fall-01	NA	NA	NA	NA	NA
Win-02	NA	NA	NA	NA	NA
Spr-02*	57	53	0 63	ND	ND
Sum-02	1,300	350	6 1	2 5	1 8
Fall-02	660	450	8 0	3 3	ND
Win-03	240	1 200	9.8	4 3	10
Spr-03	278	1.580	13 0	6.71	51 9
Sum-03	430	1,400	14	ND	15

13-MW-6	TCE	cis-1,2-DCE
Win-94	NA	NA
Fall-97	69	3
Spr-00	NA	NA
Sum-00	NA	NA
Win-01	NA	NA
Spr-01	NA	NA
Sum-01	NA	NA
Fall-01	NA	NA
Win-02	7 2	2 7
Spr-02*	8 5	0.83
Sum-02	4 7	ND
Fall-02	3 2	3.2
Win-03	4 2	ND
Spr-03	4 10	0 53
Sum-03	3.4	0.36

13-MW-2	TCE	cis-1,2-DCE	trans-1,2-TCE
Win-94	548	112	1 9
Fall-97	ND	ND	ND
Spr-00	NA	NA	NA
Sum-00	NA	NA	NA
Win-01	NA	NA	NA
Spr-01	NA	NA	NA
Sum-01	NA	NA	NA
Fall-01	NA	NA	NA
Win-02	2 2	3.3	ND
Spr-02*	2 3	1 8	ND
Sum-02	1 4	1 1	ND
Fall-02	1 1	3.6	ND
Win-03	1 8	0 85	ND
Spr-03	1 44	0.66	ND
Sum-03	1.3	0.57	ND

13-MW-3	TCE
Win-94	ND
Fall-97	0.21
Spr-00	ND
Sum-00	NA
Win-01	ND
Spr-01	ND
Sum-01	ND
Fall-01	ND
Win-02*	ND
Spr-02	ND
Sum-02	ND
Fall-02	ND
Win-03	0.56
Spr-03	ND
Sum-03	ND

13-MW-8	Key COCs
Win-94	NA
Fall-97	ND
Spr-00	ND
Sum-00	NA
Win-01	ND
Spr-01	ND
Sum-01	ND
Fall-01	ND
Win-02*	ND
Spr-02	ND
Sum-02	ND
Fall-02	ND
Spr-03	ND
Sum-03	ND

LEGEND

- 200 — CONTOUR OF GROUND SURFACE ELEVATION IN FEET ABOVE MSL (5-FOOT INTERVALS) (NAVD 1988)
- RAILROAD
- FENCE
- PAVED ROAD OR STREET
- DIRT ROAD
- TRAIL
- 1788 — BUILDING
- CONCRETE OR PAVED AREAS
- LAKE
- VEGETATION LINE
- UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
- LAKE SURFACE ELEVATION CONTOUR
- 13-MW-2 — GROUNDWATER MONITORING WELL
- NA — NOT ANALYZED
- ND — NOT DETECTED; RESULT IS LESS THAN THE METHOD DETECTION LIMIT
- * — INSTALLED MICROPURGE PUMP
- ** — REMOVED MICROPURGE PUMP RESUME SAMPLING WITH GRUNDFOS PUMP

NOTE: ALL RESULTS IN μg/L

N

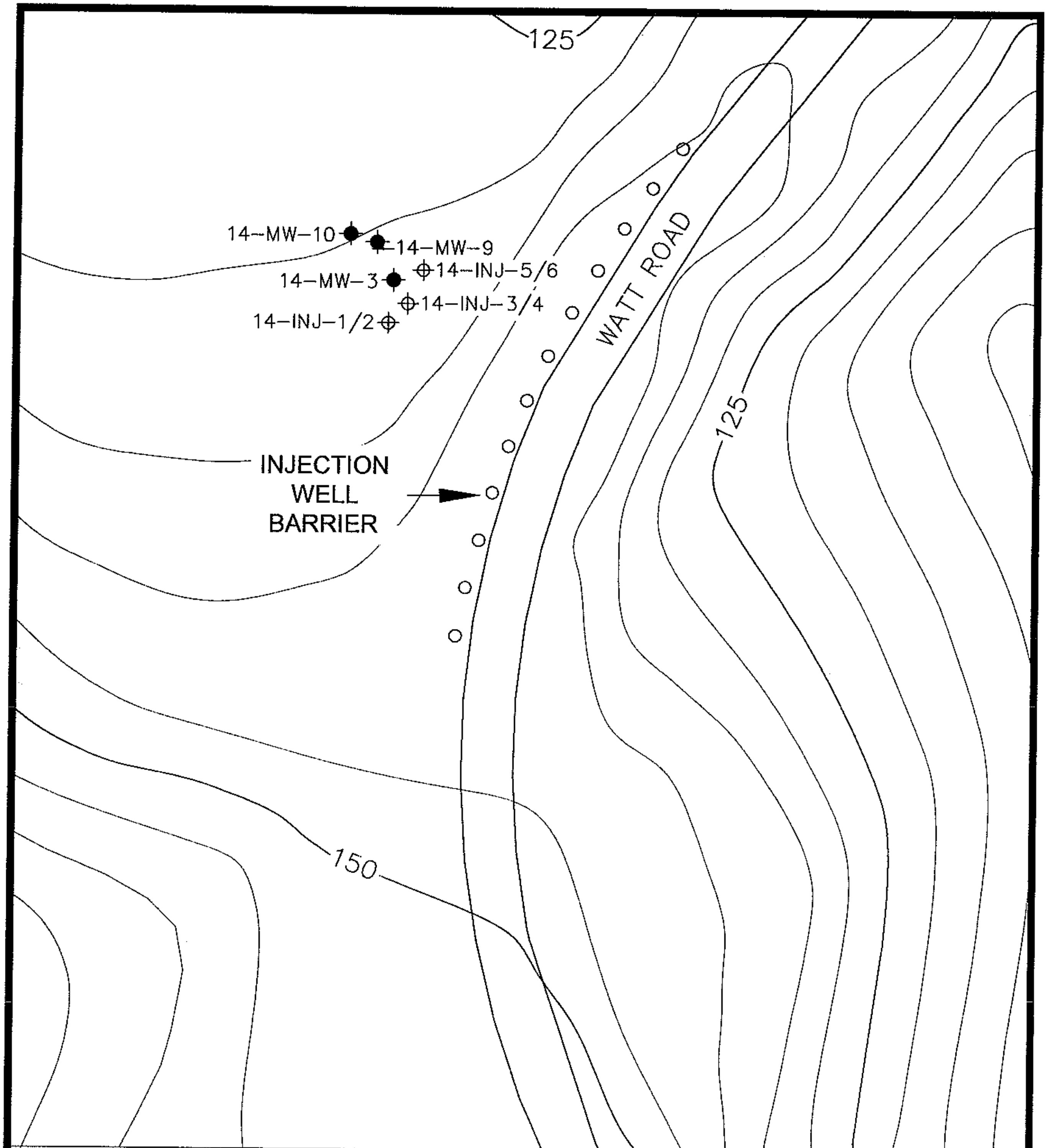
0 350' 700' 1050'
SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
ABRES-A LAUNCH COMPLEX AND ABRES-A LAKE
HISTORICAL ANALYTICAL RESULTS OF
KEY CONTAMINANTS OF CONCERN
SUMMER 2003

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO	DATE	DRAWN BY	MADE FROM	ACAD FILE #	Figure
99046-06	4/8/05	RANDALL	TAB14 TAB15	4040	2-4



LEGEND

- 200 — CONTOUR LINE, 5 - FOOT INTERVALS (FEET ABOVE MSL NAVD 1988)
- —x— FENCE
- PAVED ROAD OR STREET
- DIRT ROAD
- 1788 BUILDING
- CONCRETE OR PAVED AREAS
- VEGETATION LINE
- UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
- 14-MW-3 GROUNDWATER MONITORING WELL
- 14-INJ-1/2 INJECTION WELL
- 14-B-3 SOIL BORING
- PROPOSED INJECTION WELLS

N

0 25' 50'
SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
LOCATION OF INJECTION WELLS
AT WATT ROAD

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO.	DATE	DRAWN BY	MADE FROM	GIS FILE #	FIGURE NO.
99046-06	10/12/04	RANDALL	TAB14	4360	2-5

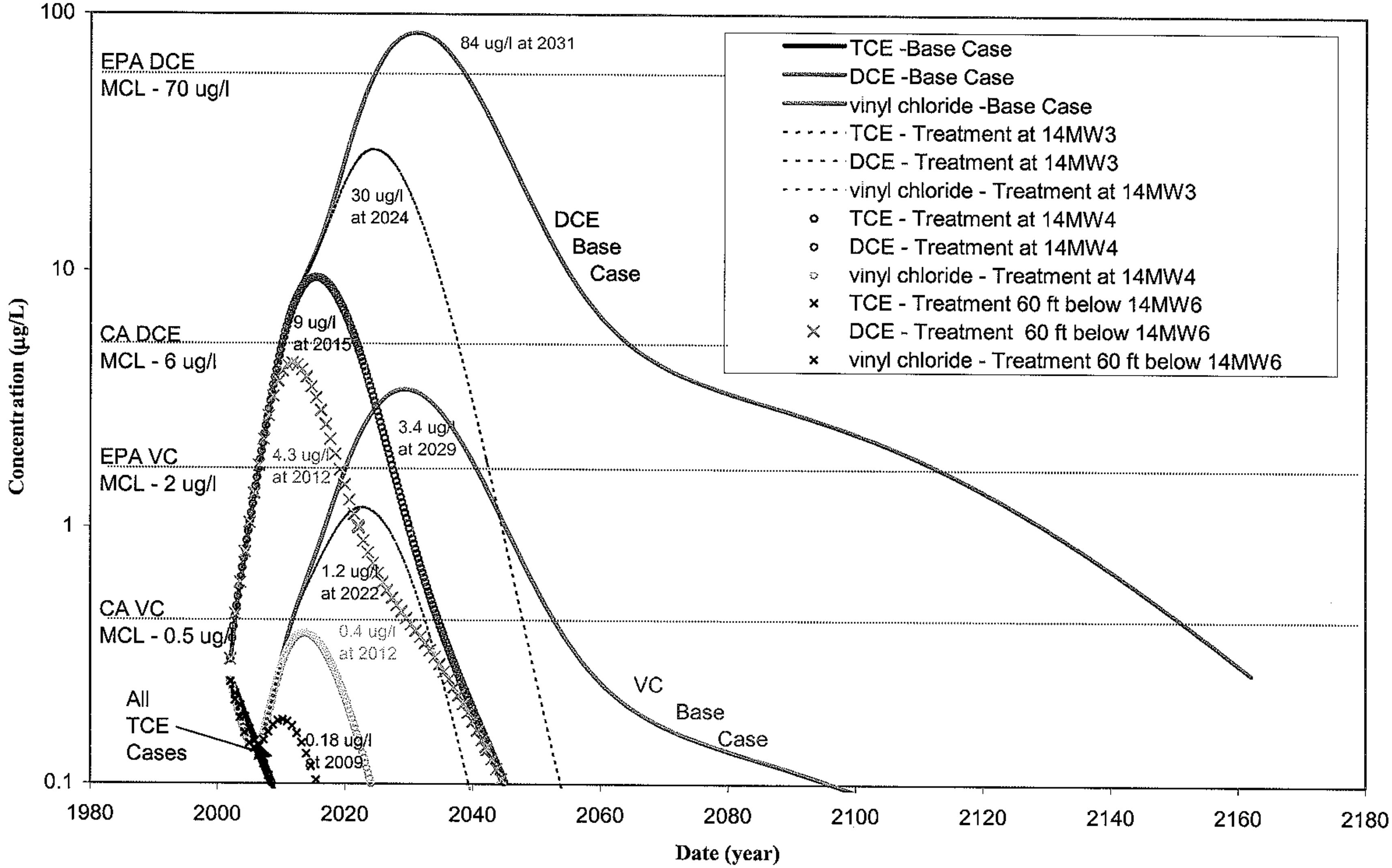
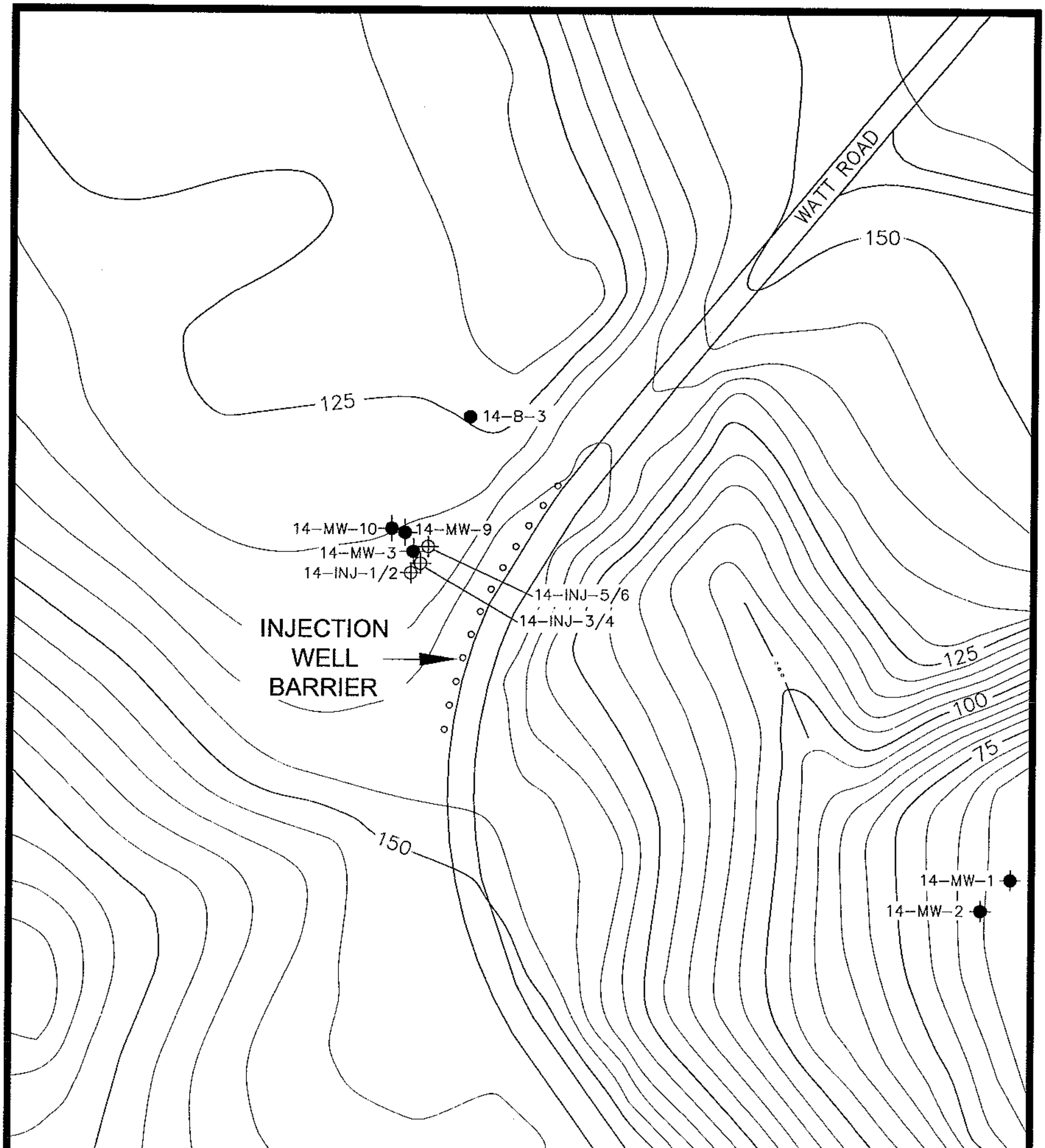


Figure 2-6. RT3D Model Predicted VOC Concentrations at Sentry Well 14-MW-5 During Natural Attenuation and Active Treatment Scenarios at Wells 14-MW-3, 14-MW-4, and 14-MW-6.



LEGEND

200 CONTOUR LINE, 5 – FOOT INTERVALS (FEET ABOVE MSL, NAVD 1988)

FENCE

PAVED ROAD OR STREET

DIRT ROAD

1788 BUILDING

CONCRETE OR PAVED AREAS

VEGETATION LINE

UNLINED DRAINAGE ROUTE AND FLOW DIRECTION

14-MW-3 GROUNDWATER MONITORING WELL

14-INJ-1/2 INJECTION WELL

14-B-3 SOIL BORING

PROPOSED INJECTION WELLS

N

0 50' 100'

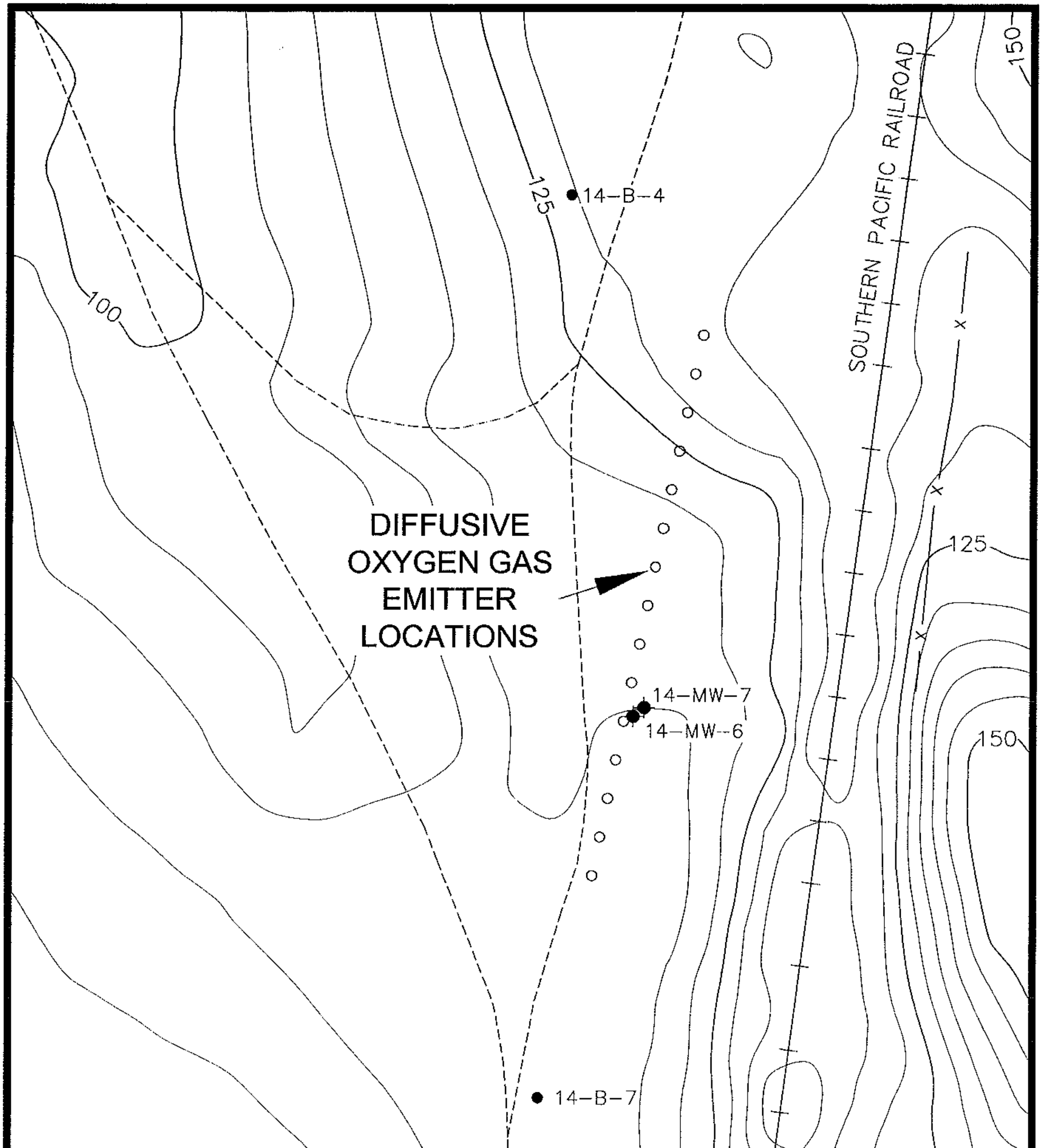
SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
LOCATION OF PROPOSED
INJECTION WELLS AT WATT ROAD

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO	DATE	DRAWN BY	MADE FROM	GIS FILE #	FIGURE NO.
99046-06	10/12/04	RANDALL	TAB14	4061	4-1



LEGEND

- 200 CONTOUR LINE, 5 - FOOT INTERVALS (FEET ABOVE MSL NAVD 1988)
- FENCE
- PAVED ROAD OR STREET
- DIRT ROAD
- 1788 BUILDING
- CONCRETE OR PAVED AREAS
- VEGETATION LINE
- UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
- 14-MW-6 GROUNDWATER MONITORING WELL
- 14-B-7 SOIL BORING
- PROPOSED INJECTION WELL

N

0 50' 100'

SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
PROPOSED WELL EMITTER
LOCATIONS WEST OF RAILROAD TRACKS

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO	DATE	DRAWN BY	MADE FROM	GIS FILE #	FIGURE NO.
99046-06	2/3/05	RANDALL	TAB14	4060	4-2

TABLES

Table 2-2
VOCs in Discrete-Depth Groundwater Samples (µg/L)
EPA Method SW8260
IRP Site 13 Cluster
Vandenberg AFB, California

Sample Location	13-MW-6	13-MW-6	13-MW-7	13-MW-7	13-MW-7
Collection Date	10-Sep-1997	11-Sep-1997	12-Sep-1997	15-Sep-1997	15-Sep-1997
Depth (feet bgs)	32	42	31	44	53
Sample ID	V13MW6-35W	V13MW6-45W	V13MW7-31W	V13MW7-41W	V13MW7-53W
Acetone	ND U g	ND U g	13 g	56 g	ND U g
Benzene	ND U g	ND U g	0.26 J q	ND U g	ND U g
Bromoform	ND U g	ND U g	ND U g	ND U g	ND U g
2-Butanone	ND U g	ND U g	2.9 g	8.8 g	ND U g
Carbon disulfide	ND U g	ND U g	ND U g	0.49 J q	ND U g
Chloroform	ND U g	ND U g	ND U g	ND U g	ND U g
Dibromochloromethane	ND U g	ND U g	ND U g	ND U g	ND U g
1,1-Dichloroethene	ND U g	ND U g	0.65 g	ND U g	1.1 g
cis-1,2-Dichloroethene	14 g	ND U g	150 g	95 g	220 g
Methylene chloride	ND U g	ND U g	ND U g	ND U g	ND U g
trans-1,2-Dichloroethene	0.3 J q	ND U g	1.6 g	1.1 g	2.6 g
Toluene	ND U g	ND U g	0.29 J q	ND U g	ND U g
Trichloroethene	22 J f	ND UJ f	94 g	47 J f	1,100 J f
Trichlorofluoromethane	ND U g	ND U g	ND U g	ND U g	ND U g
Vinyl chloride	ND U g	ND U g	ND U g	ND U g	ND U g
All other analytes	ND	ND	ND	ND	ND

Table 2-2
VOCs in Discrete-Depth Groundwater Samples (µg/L)
EPA Method SW8260
IRP Site 13 Cluster
Vandenberg AFB, California

Sample Location	**13-MW-7**	**14-B-3**	**14-MW-3**	**14-MW-7**	**14-MW-8**
Collection Date	**15-Sep-1997**	**25-Sep-1997**	**29-Sep-1997**	**22-Aug-2000**	**22-Aug-2000**
Depth (feet bgs)	**53**	**75**	**85**	**65**	**85**
Sample ID	**V99W9 (D)**	**V14B3-78**	**V14MW3H-88**	**V14NW7H-65**	**V14MW8T**
Acetone	ND U g	ND U g	4 J q	ND U g	ND U g
Benzene	ND U g	0.16 J q	ND U g	ND U g	ND U g
Bromoform	ND U g	ND U g	ND U g	ND U g	ND U g
2-Butanone	ND U g	ND U g	ND U g	ND U g	ND U g
Carbon disulfide	ND U g	0.12 B,J k, q	ND U g	ND U g	ND U g
Chloroform	ND U g	ND U k	ND U g	ND U g	ND U g
Dibromochloromethane	ND U g	ND U g	ND U g	ND U g	ND U g
1,1-Dichloroethene	1.4 g	ND U g	ND U g	ND U g	ND U g
cis-1,2-Dichloroethene	220 g	30 g	78 g	ND U g	ND U g
Methylene chloride	ND U g	ND U g	ND U g	ND U g	ND U g
trans-1,2-Dichloroethene	2.7 g	2.7 g	2 g	ND U g	ND U g
Toluene	ND U g	ND U g	ND U g	ND U g	ND U g
Trichloroethene	1,200 J f	0.19 J q	ND U g	ND U g	ND U g
Trichlorofluoromethane	ND U g	ND U g	ND U g	ND U g	ND U g
Vinyl chloride	ND U g	ND U g	7 g	ND U g	ND U g
All other analytes	ND	ND	ND	ND	ND

Table 2-2
VOCs in Discrete-Depth Groundwater Samples (µg/L)
EPA Method SW8260
IRP Site 13 Cluster
Vandenberg AFB, California

Data Validity Qualifiers:

J - The analyte was positively identified and the result is usable; however the analyte concentration is an estimated value.
U - The analyte was not detected at or above the RDL.
UJ - The analyte was not detected above the RDL; however, the RDL is uncertain and may be elevated above normal levels.

Data Validity Comments:

f - The duplicate/replicate sample's relative percent difference was outside the control limit.
g - The data met prescribed criteria as detailed in the QAPP.
k - The analyte was found a field blank.
q - The analyte detection was below the PQL.

Definitions:

bgs - below ground surface
ID - identification
µg/L - micrograms per liter
ND - not detected

Note:

1 - Instrument detection limits and method detection limits for each analyte are provided in Appendix G of the Draft RI Report (Tetra Tech, Inc. 2004).

Table 2-3
Summary of Key Organic Contaminants of Concern in Groundwater (µg/L)
IRP Site 13 Cluster (ABRES-A Launch Complex and ABRES-A Lake)
Vandenberg AFB, California

TCE

	Win-94	Fall-97	Spr-00	Sum-00	Win-01	Spr-01	Sum-01	Fall-01	Win-02	Spr-02	Sum-02	Fall-02	Win-03	Spr-03	Sum-03
13-MW-1	69.5	980	NA	NA	NA	NA	NA	NA	NA	57	1,300	660	240	278	430
13-MW-2	548	ND	NA	NA	NA	NA	NA	NA	2.2	2.3	1.4	1.1	1.8	1.44	1.3
13-MW-3	ND	0.21	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	0.56	ND	ND
13-MW-6	NA	69	NA	NA	NA	NA	NA	NA	7.2	8.5	4.7	3.2	4.2	4.10	3.4
13-MW-7	NA	1,000	NA	NA	NA	NA	NA	NA	NA	660	1,000	620	920	942	760
13-MW-8	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-1	ND	ND	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND
14-MW-2	ND	ND	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND
14-MW-3	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-4	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-5	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-6	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-7	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	0.52	ND	ND	ND	ND
14-MW-8(B)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(T)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

***trans* -1,2-DCE**

	Win-94	Fall-97	Spr-00	Sum-00	Win-01	Spr-01	Sum-01	Fall-01	Win-02	Spr-02	Sum-02	Fall-02	Win-03	Spr-03	Sum-03
13-MW-1	11.8	9.7	NA	NA	NA	NA	NA	NA	NA	0.63	6.1	8.0	9.8	13.0	14
13-MW-2	1.09	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-3	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-MW-6	NA	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-7	NA	ND	NA	NA	NA	NA	NA	NA	NA	11	3.4	4.2	2.2	2.69	2.2
13-MW-8	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-1	ND	ND	NA	NA	NA	NA	NA	NA	NA	1.2	ND	ND	ND	ND	ND
14-MW-2	9.03	2	NA	NA	NA	NA	NA	NA	NA	10	5.3	5.2	4.4	4.16	4.4
14-MW-3	NA	6.8	11	NA	8.5	15	8.7	20	12	21	9.4	8.1	9.3	9.45	9.4
14-MW-4	NA	NA	0.81	NA	ND	ND	ND	0.59	0.56	1.6	0.81	3.4	1.4	0.81	0.51
14-MW-5	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-6	NA	NA	ND	NA	ND	ND	ND	ND	ND	0.81	ND	2.9	ND	0.15	ND
14-MW-7	NA	NA	NA	0.94	ND	ND	ND	1.2	1.2	3.6	ND	3.4	0.71	0.61	0.54
14-MW-8(B)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(T)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 2-3
Summary of Key Organic Contaminants of Concern in Groundwater (µg/L)
IRP Site 13 Cluster (ABRES-A Launch Complex and ABRES-A Lake)
Vandenberg AFB, California

	cis -1,2-DCE														
	Win-94	**Fall-97**	**Spr-00**	**Sum-00**	**Win-01**	**Spr-01**	**Sum-01**	**Fall-01**	**Win-02**	**Spr-02**	**Sum-02**	**Fall-02**	**Win-03**	**Spr-03**	**Sum-03**
13-MW-1	1,220	1,100	NA	NA	NA	NA	NA	NA	NA	53	350	450	1,200	1,580	1,400
13-MW-2	112	ND	NA	NA	NA	NA	NA	NA	3.3	1.8	1.1	3.6	0.85	0.66	0.57
13-MW-3	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-MW-6	NA	3	NA	NA	NA	NA	NA	NA	2.7	0.83	ND	3.2	ND	0.53	0.36
13-MW-7	NA	150	NA	NA	NA	NA	NA	NA	NA	730	390	230	270	320	340
13-MW-8	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-1	ND	1.30	NA	NA	NA	NA	NA	NA	NA	6.1	2.4	5.7	4.2	2.19	3.5
14-MW-2	997	150	NA	NA	NA	NA	NA	NA	NA	650	450	320	410	410	440
14-MW-3	NA	210	360	NA	310	310	300	320	360	440	310	210	360	361	320
14-MW-4	NA	NA	25	NA	4.7	6.6	4.7	10	17	31	41	26	43	23.7	12
14-MW-5	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-6	NA	NA	4.5	NA	4.2	7.3	5.6	6.8	5.3	8.9	4.5	6.9	5.1	3.03	2.5
14-MW-7	NA	NA	NA	42	12	13	6.1	42	39	86	20	42	27	28.2	28
14-MW-8(B)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(T)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

	1,1-DCE														
	Win-94	**Fall-97**	**Spr-00**	**Sum-00**	**Win-01**	**Spr-01**	**Sum-01**	**Fall-01**	**Win-02**	**Spr-02**	**Sum-02**	**Fall-02**	**Win-03**	**Spr-03**	**Sum-03**
13-MW-1	3.31	ND	NA	NA	NA	NA	NA	NA	NA	ND	2.5	3.3	4.3	6.71	ND
13-MW-2	ND	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-3	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-MW-6	NA	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-7	NA	ND	NA	NA	NA	NA	NA	NA	NA	5.8	1.8	ND	1.2	2.24	ND
13-MW-8	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-1	ND	ND	NA	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND
14-MW-2	3.07	0.48	NA	NA	NA	NA	NA	NA	NA	3.8	2.0	1.1	1.5	1.90	ND
14-MW-3	NA	0.60	ND	NA	1.2	1.4	1.0	1.8	1.6	3.0	1.4	ND	ND	1.86	ND
14-MW-4	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-5	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-6	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-7	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(B)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(T)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 2-3
Summary of Key Organic Contaminants of Concern in Groundwater (µg/L)
IRP Site 13 Cluster (ABRES-A Launch Complex and ABRES-A Lake)
Vandenberg AFB, California

	Vinyl chloride														
	Win-94	Fall-97	Spr-00	Sum-00	Win-01	Spr-01	Sum-01	Fall-01	Win-02	Spr-02	Sum-02	Fall-02	Win-03	Spr-03	Sum-03
13-MW-1	0.73	6	NA	NA	NA	NA	NA	NA	NA	ND	1.8	ND	10	51.9	15
13-MW-2	ND	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-3	ND	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-MW-6	NA	ND	NA	NA	NA	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND
13-MW-7	NA	ND	NA	NA	NA	NA	NA	NA	NA	0.76	ND	ND	ND	0.95	ND
13-MW-8	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-1	ND	ND	NA	NA	NA	NA	NA	NA	NA	14	8.3	ND	ND	ND	0.29
14-MW-2	49.3	7.4	NA	NA	NA	NA	NA	NA	NA	5.6	5.0	2.4	4.2	9.33	6.1
14-MW-3	NA	14	37	NA	20	27	20	25	18	20	18	11	16	38.3	20
14-MW-4	NA	NA	15	NA	0.70	0.52	ND	1.2	6.3	7.4	11	7.7	23	21.0	7.8
14-MW-5	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-6	NA	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-7	NA	NA	NA	ND	ND	ND	ND	0.83	ND	ND	ND	ND	1.7	8.14	3.4
14-MW-8(B)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
14-MW-8(T)	NA	NA	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Definitions:

(B) - bottom of saturated zone
DCE - dichloroethene
µg/L - micrograms per liter
NA - not analyzed
ND - not detected; result is less than the MDL
(T) - top of saturated zone
TCE - trichloroethene

Table 5-1
Schedule for Interim Removal Action at Site 13 Cluster

Item	Activity	Anticipated Start Date	Completion Date
1	Vandenberg AFB review of Preliminary Draft EE/CA	June 24, 2004	September 23, 2004
2	Draft EE/CA preparation	September 23, 2004	October 15, 2004
3	Regulatory review Draft EE/CA by DTSC and RWQCB	October 15, 2004	January, 14 2005
4	Prepare Response to Regulatory Comments	January, 14 2005	February 25, 2005
5	Preparation of Draft Final EE/CA and Preliminary Draft 13C IRA Work Plan	March 1, 2005	March 7, 2005
6	Review by Vandenberg AFB	March 7, 2005	March 21, 2005
7	Submit Draft Final EE/CA (1) with Draft IRA Work Plan to DISC & RWQCB	April 12, 2005	April 12, 2005
8	Regulatory review by DTSC and RWQCB	April 12, 2005	May 11, 2005
9	Respond to regulatory comments on Draft Final EE/CA and Draft IRA Work Plan	May 11, 2005	May 16, 2005
10	Receive regulatory concurrence with responses	May 20, 2005	May 20, 2005
11	Vandenberg AFB publishes Notice of Availability of Public Draft EE/CA in the administrative record and a brief description of the Public Draft EE/CA in major local newspapers, and public notice of CEQA documents – Public Participation Period	May 23, 2005	June 23, 2005
12	EE/CA Final with Public Response, Attach Public Response to EE/CA, Send Final EE/CA to Administrative Record	June 27, 2005	July 1, 2005
13	Initiate IRA	July 1, 2005	TBD
14	Preparation of final IRA Closure Letter Report	TBD	TBD

Definitions:

DTSC - Department of Toxic Substances Control
EE/CA - engineering evaluation/cost analysis
IRA - interim removal action
RWQCB - Regional Water Quality Control Board
TBD – to be determined

Note:

(1) The State regulatory agencies will be provided an opportunity to review and approve the Draft IRA Work Plan prior to its inclusion in the Final EE/CA

A GROUNDWATER TREATABILITY STUDY REPORT FOR SITE 13C

T65-2036
A250-48

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, California 93110-2847
Telephone (805) 681-3100
Fax (805) 681-3108
e-mail ttsba@tetratech.com

10 February 2005

Ms. Kathleen Gerber
Department of the Air Force
AFCEE/ICS
806 13th Street, Suite 116
Vandenberg AFB, CA 93437

Subject: Groundwater Treatability Study Report for Site 13 Cluster, Vandenberg Air Force Base (AFB), California

Reference: a) Contract No. F11623-94-D-0027, Task Order RL 41
b) Final Groundwater Treatability Study Work Plan for Site 13 Cluster, May 2003

Dear Ms. Gerber:

With this letter, Tetra Tech, Inc. is submitting results of groundwater monitoring to support the groundwater treatability study at Site 13 Cluster. The groundwater treatability study was designed to assess the effect of injecting an electron donor into the saturated zone to enhance the development of reducing (anaerobic) conditions to support reductive dechlorination of chlorinated solvents, primarily *cis*-1,2-DCE, present in groundwater at the head of the paleochannel at Site 13, near Watt Road (Figure 1). The selected electron donor consisted of Hydrogen Release Compound, Extended Release Formula (HRC-X), and Primer, both products manufactured by Regenesis. These products are designed to degrade and slowly release hydrogen to support a biologically mediated reductive dechlorination process over a period of up to 3 to 4 years.

The field activities and sampling and analytical methodologies were performed in accordance with the Final Groundwater Treatability Study Work Plan [work plan] (Reference b). The treatability study encompassed drilling and well installation activities, groundwater monitoring for monitored natural attenuation (MNA) and metabolic acid breakdown products, and substrate injection. A summary of the methods and results of the treatability study are discussed below.

METHODS

Drilling activities for the treatability study occurred in two mobilizations: 30 July 2003 to 5 August 2003 and 15 October 2003 to 29 October 2003. Wells 14-MW-9, 14-INJ-5, and 14-INJ-6 were drilled using the hollow-stem-auger (HSA) method during the first mobilization. Injection wells 14-INJ-5 and 14-INJ-

6 were installed as nested wells within a single borehole Difficulties with heaving sands below the water table realized during HSA drilling mandated a change in drilling method for the remaining wells. During the second mobilization, monitoring well 14-MW-10 and injection wells 14-INJ-1,14-INJ-2, 14-INJ-3, and 14-INJ-4 were installed using sonic drilling technology. Wells 14-INJ-1 and 14-INJ-2, and 14-INJ-3 and 14-INJ-4 were installed as nested injection well pairs within a single borehole. Monitoring well construction details are summarized in Table 1. Injection well and monitoring well construction details are also shown on boring logs included in Appendix A.

Sample recovery using the HSA method was limited, especially in saturated sediments due to the presence of heaving sands Sample recovery using the sonic drilling method, however, yielded nearly complete recovery, allowing a thorough examination of sediments in the treatment zone. Based on drilling cuttings observed during the well installation program, the paleochannel subsurface consists of a relatively uniform sequence of poorly graded dune sands and alluvial deposits from grade to about 115 feet bgs Groundwater occurs at approximately 90 feet bgs. Below a depth of about 115 feet bgs, sands were interbedded with discontinuous, thin clay lenses, silty sand beds, and organic peat and clay beds (Appendix A) The Monterey Shale Formation, located at approximately 150 feet bgs, defines the lower boundary of the aquifer

Injection wells 14-INJ-1, 14-INJ-3, and 14-INJ-5 were each screened across the upper aquifer (e g. approximately 90 to 115-feet below ground surface [bgs]), while injection wells 14-INJ-2 and 14-INJ-4 are screened across the lower aquifer (e g. approximately 125 to 150-feet bgs). Due to cherty, organic clays encountered at 129-feet bgs in the boring for 14-INJ-6, which were interpreted to indicate proximity to an upper weathered bedrock surface at this location, a shallower screen was set from 121 to 131-feet bgs (Appendix A). Monitoring well 14-MW-9 was screened to monitor the shallow injection zone, while wells 14-MW-2, 14-MW-3, and 14-MW-10 are each screened across the deeper aquifer (Table 1). Monitoring well 14-MW-3 is positioned approximately 10 feet downgradient of the injection well array, well 14-MW-9 approximately 20-feet, and well 14-MW-10 approximately 35 feet downgradient from the injection well array (Figure 1). Monitoring well 14-MW-2, located approximately 440 feet east and hydraulically upgradient from the injection well array, is the upgradient monitoring well for the treatability study.

Following installation, monitoring wells were developed in accordance with the work plan. Injection wells were developed using a decontaminated submersible pump All wells were later surveyed by a State licensed surveyor in accordance with the work plan. Investigative derived waste soils were placed in roll-off bins, and following soil characterization, the soils were disposed of at Vandenberg AFB sanitary landfill. All decontamination and purge waters were collected onsite and ultimately were transported and disposed of at the Industrial Wastewater Treatment Plant.

An initial baseline monitoring event was conducted on 10 November 2003. Injection of HRC-X and Primer was conducted on 11 through 12 November 2003 into injection wells 14-INJ-1 through 14-INJ-6. Mixing and injection of Regenesis products was completed as described in the work plan A well packer was used to isolate portions of each injection well during the injection process. Post-injection monitoring events were conducted at intervals of 10-days, 1 month, 2 months, 3 months, 6 months, and 9 months following injection. All Investigative Derived Waste and purge waters were containerized

RESULTS

Elevations above mean sea level for groundwater and ABRES-A Lake are provided in Table 1. A groundwater contour map, showing elevations measured during the summer 2004 Basewide Groundwater

Monitoring Program (BGMP), is provided as Figure 2. Groundwater flows through the treatment zone to the northwest at a gradient of 0.008 ft/ft. As shown on Table 1, the water level of ABRES-A Lake has significantly dropped during the past six months, which has likely affected the volume of groundwater moving through the treatment zone. Seasonal (i.e. late fall) declines in lake level have been documented at Site 13 Cluster for many years.

A compilation of the volume of electron donor products including HRC-X and Primer (a lactic acid product) injected into the six well array is provided in Table 2. In total, 357 pounds of Primer was injected, along with 2,332 pounds of HRC-X (diluted with approximately 50% water) into the well array.

Table 3 summarizes concentrations of trichloroethene (TCE), dichloroethene (DCE) isomers, vinyl chloride, and ethene detected in groundwater samples from monitoring wells 14-MW-2, 14-MW-3, 14-MW-9, and 14-MW-10 before and after HRC-X and Primer injection over the 9-month monitoring duration. The calculated relative percentage change for these key VOC concentrations between the baseline and the 9-month sampling round is also provided on Table 3.

Table 4 presents a complete list of the validated volatile organic compound (VOC) data for the treatability study monitoring wells. The change in concentrations of TCE, DCE isomers, vinyl chloride, and ethene since HRC-X and Primer injection are provided in graphical form as Figures 3 through 7, using molar equivalents. Historical analytical results for monitoring wells 14-MW-2 and 14-MW-3 associated with the BGMP prior to the treatability study are included on these graphs for reference of historic concentrations. Historic monitoring of groundwater in wells 14-MW-2 and 14-MW-3 document elevated concentrations of primarily *cis*-1,2-DCE in the deeper aquifer (Figures 3 and 4, respectively). Monitoring data from shallow zone well 14-MW-9 documents much lower VOC concentrations in groundwater in the shallow zone (Figure 5). Monitoring data from deep zone well 14-MW-10, located 35 feet downgradient from the injection wells, also documents a trend of declining VOC concentrations in all species over the 9-month duration of this treatability study. Total VOC contaminant concentrations expressed in molar equivalents from wells 14-MW-2 and 14-MW-3 are shown on Figure 7.

Table 5 provides laboratory analysis results for metabolic acids. These are the breakdown products of HRC-X and Primer and are an indication of the dissolution and metabolic utilization of the HRC-X and Primer products. Table 6 summarizes analytical results of water quality parameters. These include dissolved oxygen (DO), total sulfide, methane and ethene concentrations, oxidation/reduction potential (ORP), and alkalinity. In addition to the treatability study wells, these parameters are also included for well 13-MW-8, which is located upgradient of ABRES-A Lake. Figures 8, 9, and 10 present alkalinity, methane, and total sulfide concentrations measured in groundwater over the course of the treatability study.

DISCUSSION

The 9-month sampling results provide several strong indications that the treatability study achieved the desired results of creating a reductive aquifer environment and facilitating the destruction of *cis*-1,2-DCE in groundwater completely through to ethene, without a demonstrated buildup of vinyl chloride in the treatment zone above historically detected levels. The indications include key water quality parameters confirming aquifer changes, presence of metabolic acids confirming product breakdown, and VOC data confirming targeted contaminant concentration reductions.

Water quality parameters including low DO, negative ORP values, as well as increasing alkalinity, methane, and total sulfide concentrations are consistent with an interpretation of sustained reducing conditions in the treatment zone (Figures 8 through 10, respectively). In addition, the breakdown products of HRC-X and Primer (e.g., lactic, propionic, and acetic acids) have been detected in downgradient wells 14-MW-3, 14-MW-9 and 14-MW-10. Increased detectable concentrations of metabolic acids in the groundwater indicate continued breakdown of HRC-X and Primer in the injection zone.

The concentration of *cis*-1,2-DCE in well 14-MW-3 has decreased from 204 μg/L to 59 μg/L (71%), its current historic low, since HRC-X and Primer injection during November 2003. By contrast, in upgradient well 14-MW-2, *cis*-1,2-DCE declined from a baseline concentration of 288 μg/L to only 260 μg/L during the 9-month event, an 11% decline. In addition, ethene was reported at a concentration of 18 μg/L in well 14-MW-3 during this 9-month event; ethene was not detected previously at this sample location. Detection of ethene in the treatment zone is confirmation of complete dechlorination of *cis*-1,2-DCE through vinyl chloride. Based on molar equivalents of DCE and ethene, approximately 62 μg/L of DCE will degrade to 18 μg/L of ethene. Vinyl chloride concentrations are an order of magnitude less than DCE concentrations and are not indicating a buildup above the range of concentrations historically detected in wells 14-MW-2 and 14-MW-3 (see Figures 3 and 4, respectively).

In deep zone well 14-MW-10, the concentration of *cis*-1,2-DCE has decreased from 289 μg/L to 110 μg/L (62%), also at a historic low, since HRC-X and Primer injection during November 2003. Changes in concentration in well 14-MW-9 are of lower magnitude given the existing low concentrations of VOCs reported in the shallow zone.

Despite the relatively elevated concentrations of sulfate (an alternate electron acceptor that is conventionally believed to compete with the reductive dechlorination process) in upgradient and treatment zone wells at concentrations in the range of 200 mg/L, its persistence does not appear to be hindering the reductive dechlorination process. Also, the treatment zone is demonstrating the ability to accommodate destruction of a continuing *cis*-1,2-DCE source flowing into the treatment zone without introduction of non-native bacteria (i.e. no bioaugmentation).

Ongoing monitoring of the treatability study wells is scheduled to continue through the BGMP. It is expected that the favorable data trends presented in this memorandum will continue to be documented in subsequent monitoring events, given the slow release nature of the electron donor injected into the treatment zone.

CLOSING

HRC-X is a slow release formulation reportedly designed to last up to 3 to 4 years following injection into a groundwater system. Results through this 9-month event demonstrate favorable data trends with respect to sustained reducing conditions, continued breakdown and declining concentrations of targeted VOCs above background. The objectives of the treatability study are considered to have been met at this time. The treatability study wells will continue to be monitored quarterly as part of the BGMP, serving to document the continuation of the favorable data trends. An Engineering Evaluation/Cost Analysis (EE/CA) is currently in preparation that specifies an Interim Removal Action (IRA) to address cleanup of VOCs in groundwater in the paleochannel aquifer. Based in part on the favorable results of this treatability study, the technology selected in the EE/CA is an electron donor approach without bioaugmentation, similar to that used in this treatability study. The evaluation of results of the treatability study will also be incorporated into the Site 13 Cluster Feasibility Study, which is currently in preparation.

If you have any questions please contact the undersigned by telephone at (805) 681-3100, by facsimile at (805) 681-3108, or by e-mail at david.springer@tetratech.com or dave.fenity@tetratech.com.

Sincerely,

TETRA TECH, INC.

REGISTERED GEOLOGIST
DAVID S. SPRINGER
NO. 6962
STATE OF CALIFORNIA

David Springer, R.G. 6962
Principal Hydrogeologist

TETRA TECH, INC.

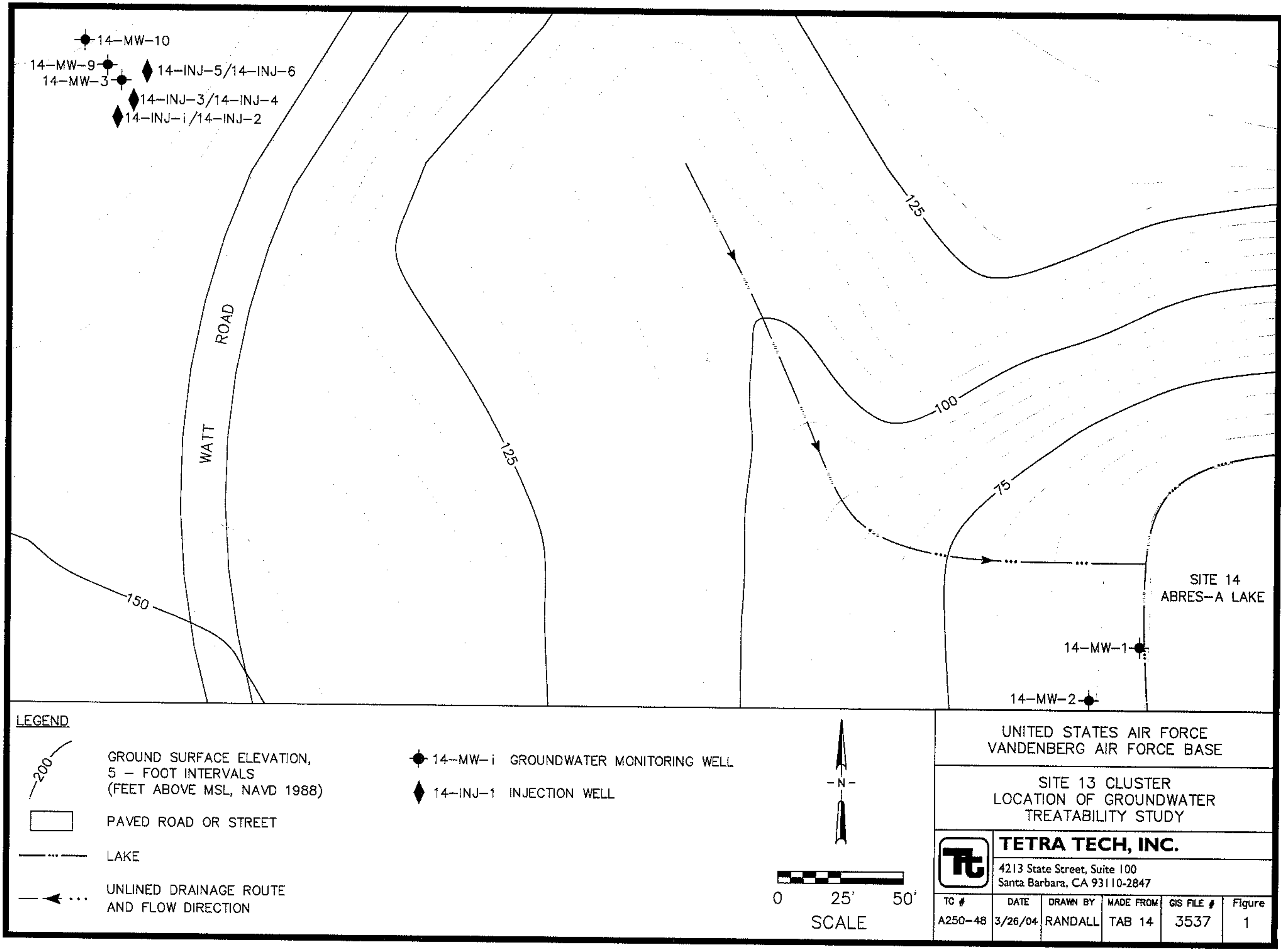
Dave Fenity
Staff Geologist

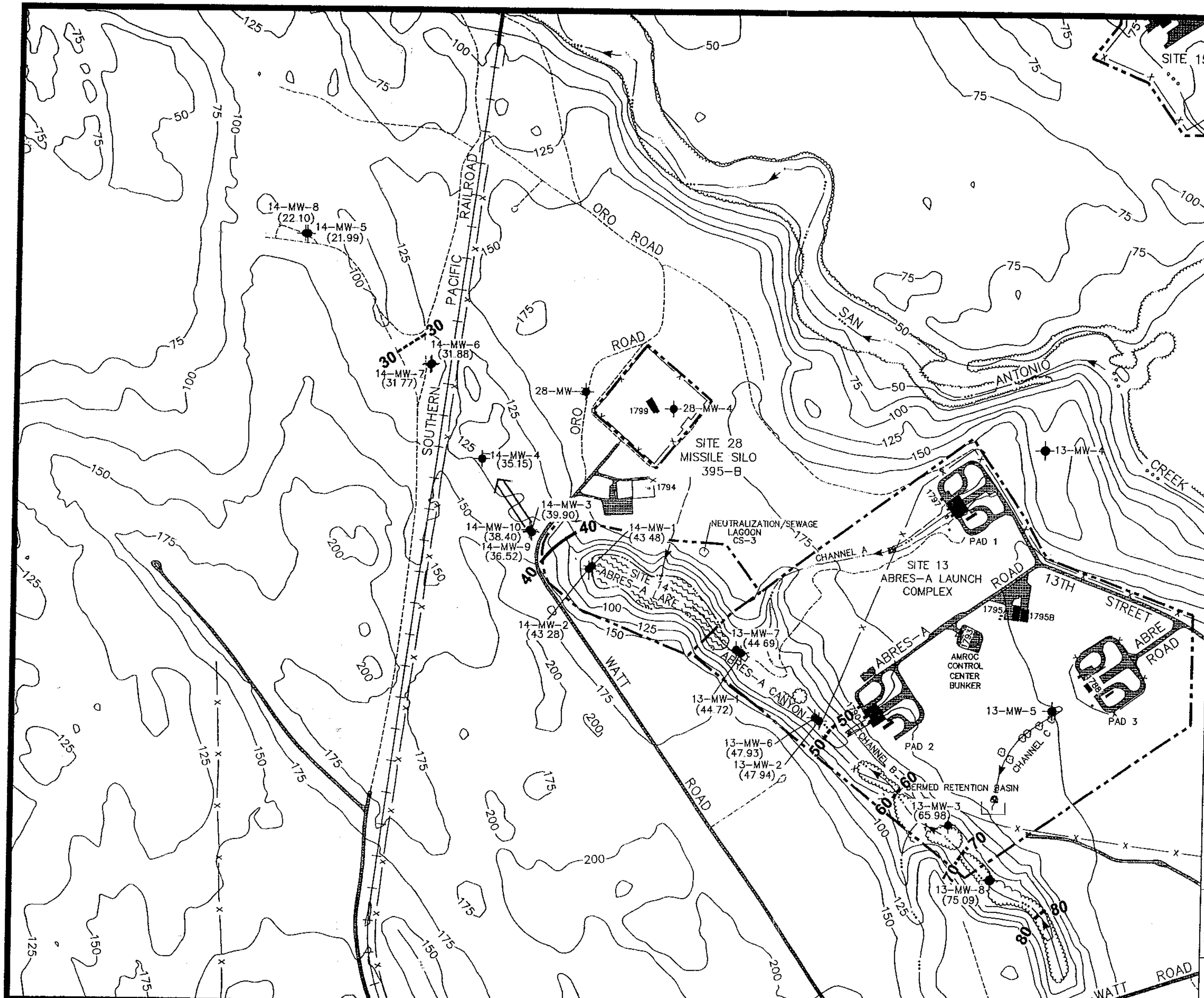
DS/DF

Distribution:

Meece, W. (RWQCB)
Than, Q. (DTSC)
Keith, J. (AFCEE/ERD)
Kephart, B. (VAFB-IRP)
Nathe, C. (VAFB-IRP)
Parsons, F. (Tetra Tech)
McNamara, K. (Tetra Tech)
Site 13 Cluster File

FIGURES


14-MW-10
14-MW-9
14-MW-3
14-INJ-5/14-INJ-6
14-INJ-3/14-INJ-4
14-INJ-i/14-INJ-2
WATT ROAD
125
125
100
75
150
SITE 14
ABRES-A LAKE
14-MW-1
14-MW-2
LEGEND
200
GROUND SURFACE ELEVATION,
5 - FOOT INTERVALS
(FEET ABOVE MSL, NAVD 1988)
PAVED ROAD OR STREET
LAKE
UNLINED DRAINAGE ROUTE
AND FLOW DIRECTION
14-MW-i GROUNDWATER MONITORING WELL
14-INJ-1 INJECTION WELL
N
0 25' 50'
SCALE
UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE
SITE 13 CLUSTER
LOCATION OF GROUNDWATER
TREATABILITY STUDY
TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847
TC # A250-48
DATE 3/26/04
DRAWN BY RANDALL
MADE FROM TAB 14
GIS FILE # 3537
Figure 1
Graphics: \Irp-Restoration\Ir-RI\Site13, 14, 28\Site 13c Treatability Study\1 ORC Injection and MWell Locs.dwg



LEGEND

- CONTOUR OF GROUND SURFACE ELEVATION IN FEET ABOVE MSL (5-FOOT INTERVALS) (NAVD 1988)
- RAILROAD
- FENCE
- PAVED ROAD OR STREET
- DIRT ROAD
- TRAIL
- BUILDING
- CONCRETE OR PAVED AREAS
- LAKE
- VEGETATION LINE
- UNLINED DRAINAGE ROUTE AND FLOW DIRECTION
- 80 —— 80 GROUNDWATER ELEVATION CONTOUR APPROXIMATED BY LINEAR INTERPOLATION (DASHED WHERE INFERRED)
- LAKE SURFACE ELEVATION CONTOUR
- INFERRED GROUNDWATER FLOW DIRECTION
- SITE BOUNDARY
- 13-MW-2 (47.94) GROUNDWATER MONITORING WELL WITH GROUNDWATER ELEVATION

NOTE: GROUNDWATER ELEVATION IN FEET ABOVE MEAN SEA LEVEL AS MEASURED IN JULY 2004

N

0 350' 700' 1050'

SCALE

UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SITE 13 CLUSTER
ABRES-A LAUNCH COMPLEX AND ABRES-A LAKE
SITE PLAN AND GROUNDWATER CONTOURS
SUMMER 2004

TETRA TECH, INC.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847

TASK NO	DATE	DRAWN BY	MADE FROM	ACAD FILE #	Figure
99047-17	10/12/04	IGE	TAB14 TAB15	4363	2

Figure 3 - Historical Contaminant Concentrations for Well 14-MW-2 (440 feet upgradient, deep screen) Site 13 Cluster Groundwater Treatability Study

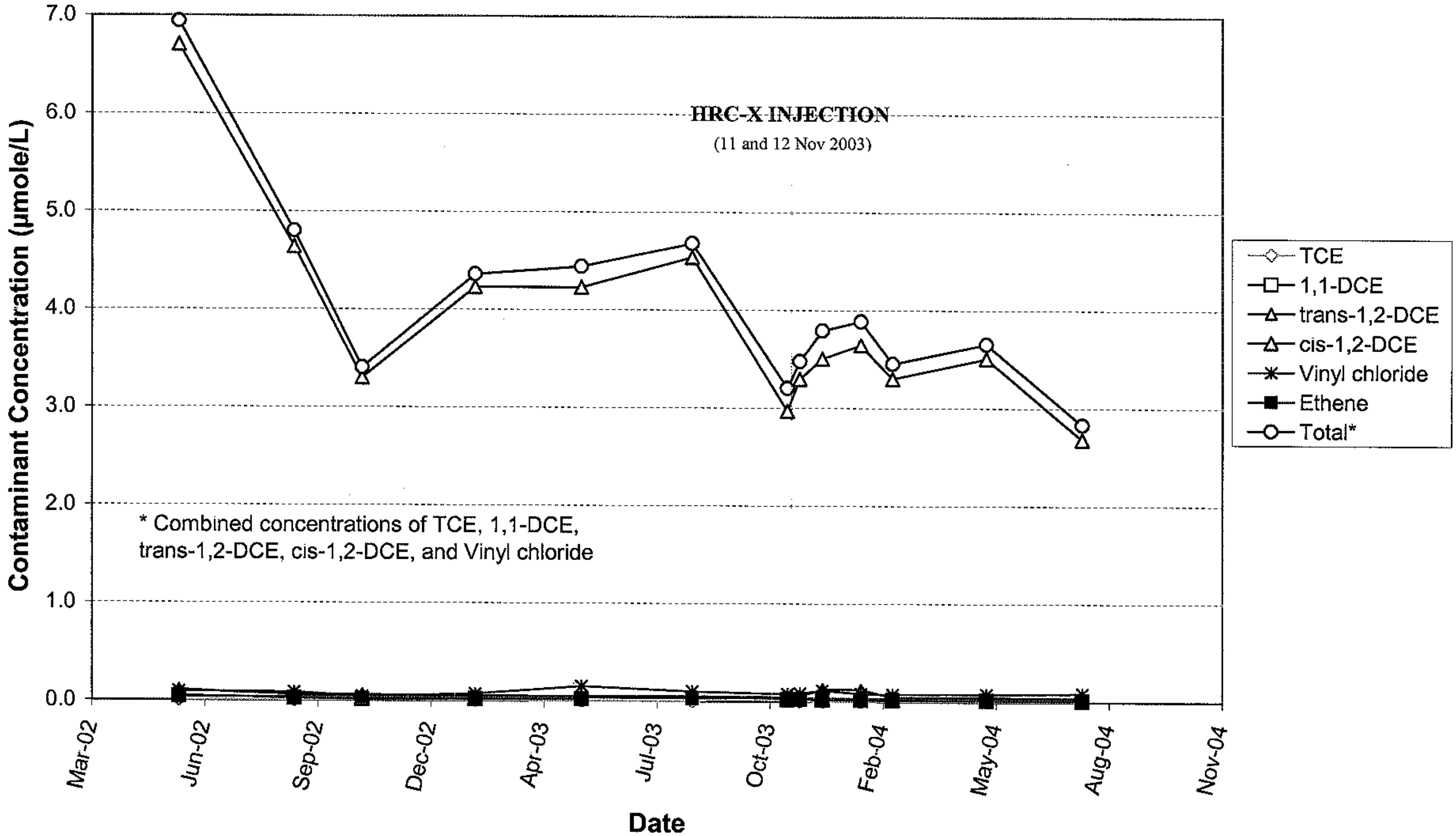


Figure 4 - Historical Contaminant Concentrations for Well 14-MW-3 (10 feet downgradient, deep screen) Site 13 Cluster Groundwater Treatability Study

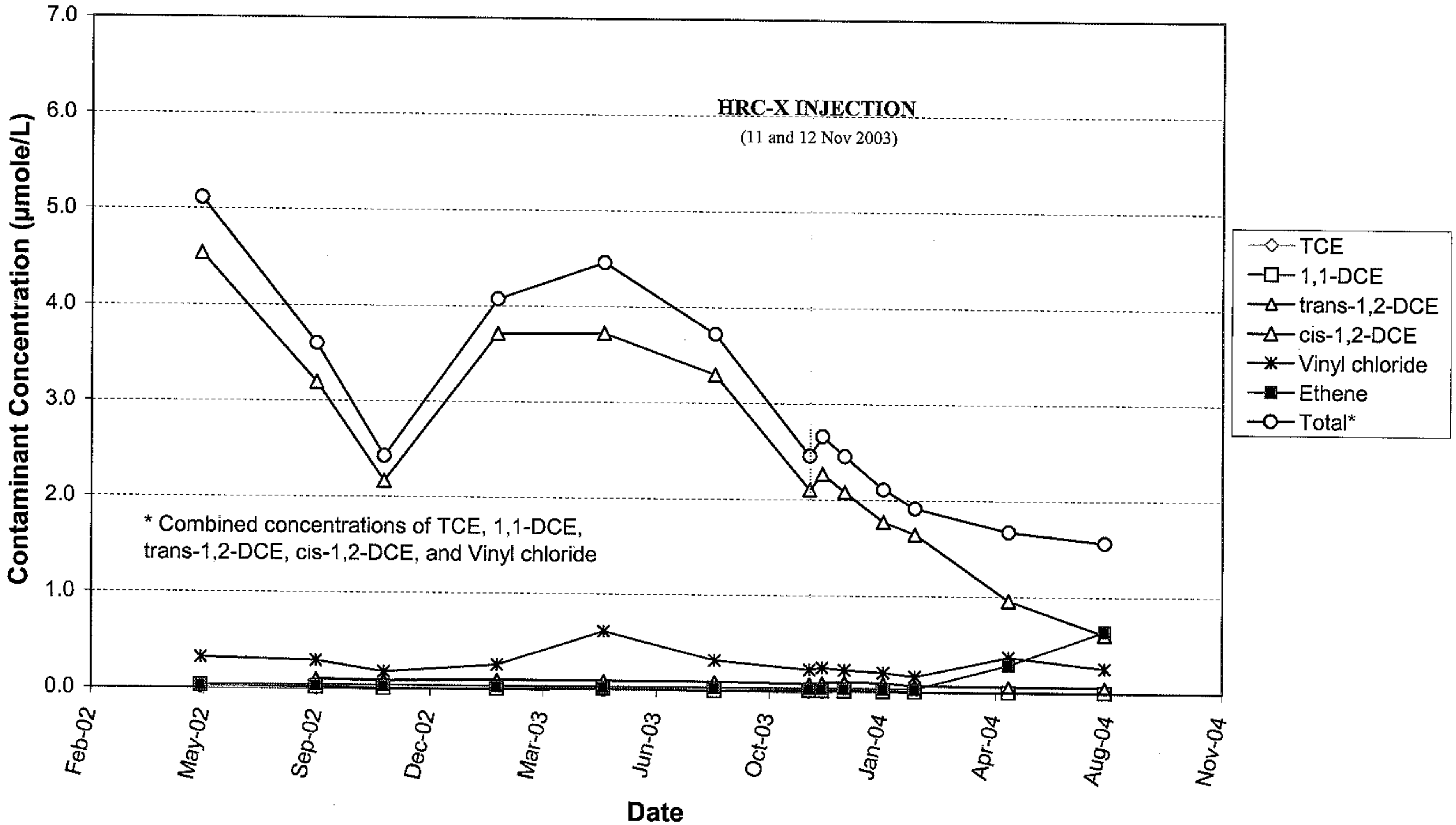


Figure 5 - Historical Contaminant Concentrations for Well 14-MW-9 (20 feet downgradient, shallow screen) Site 13 Cluster Groundwater Treatability Study

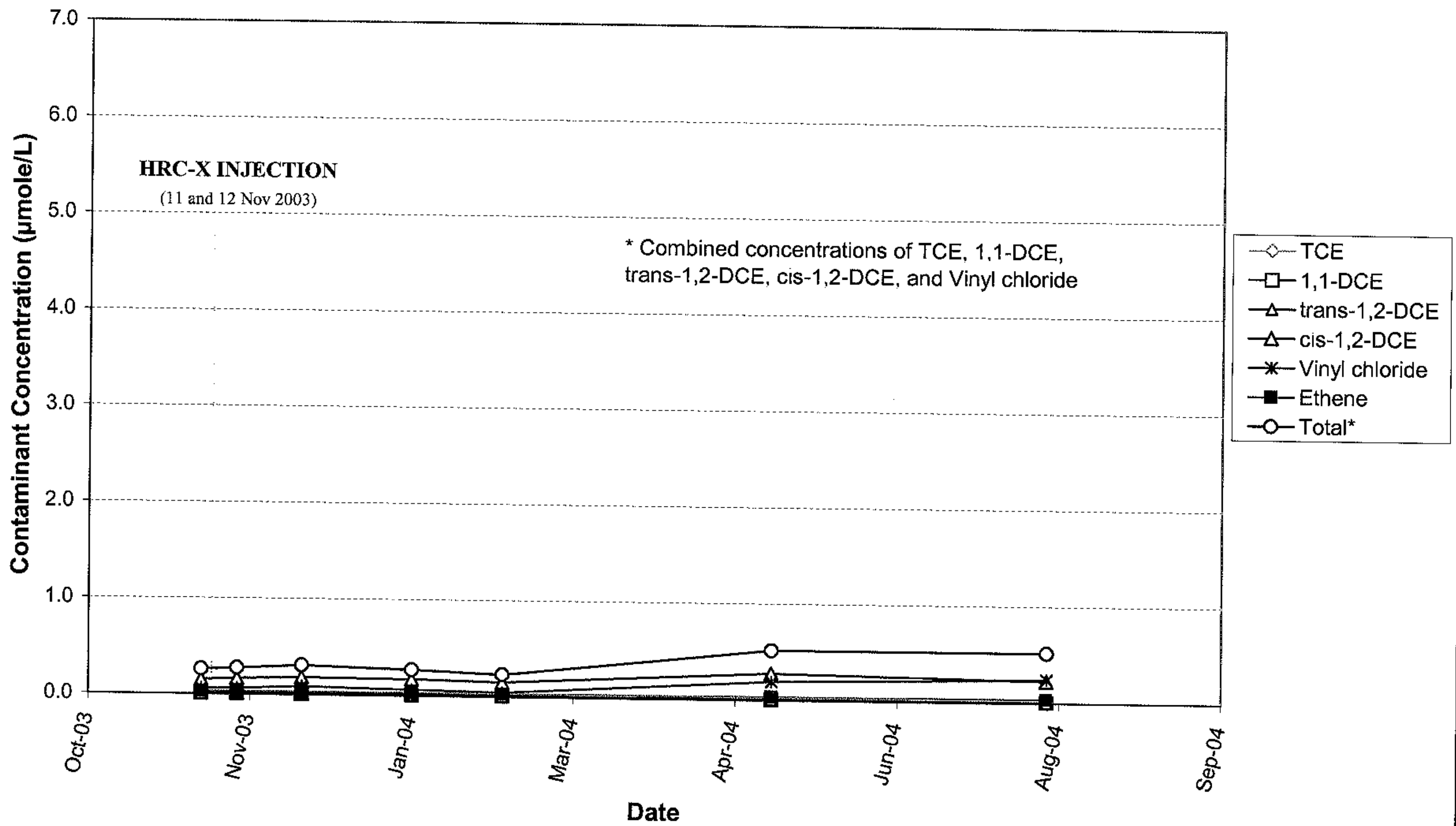


Figure 6 - Historical Contaminant Concentrations for Well 14-MW-10 (35 feet downgradient, deep screen) Site 13 Cluster Groundwater Treatability Study

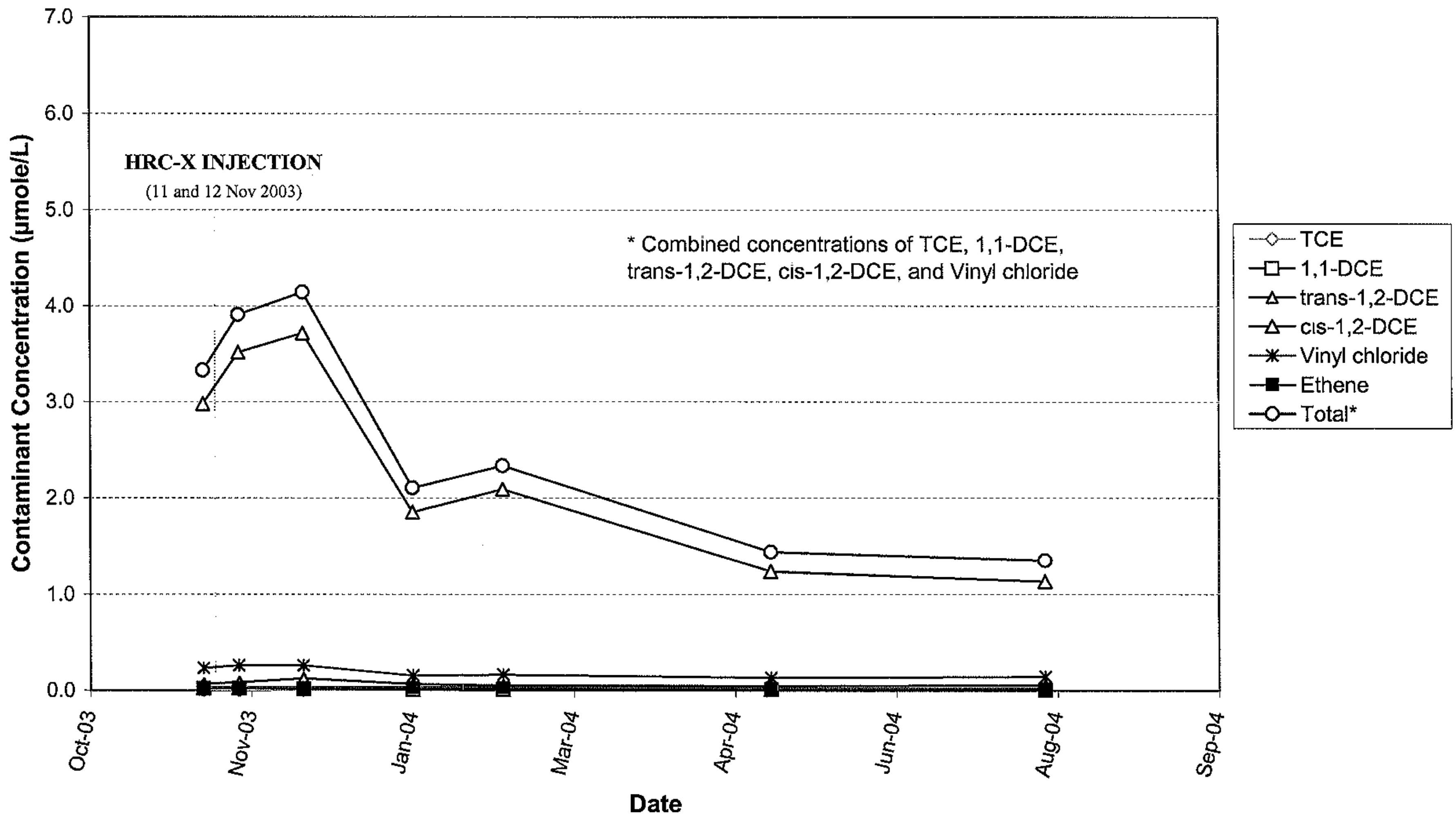
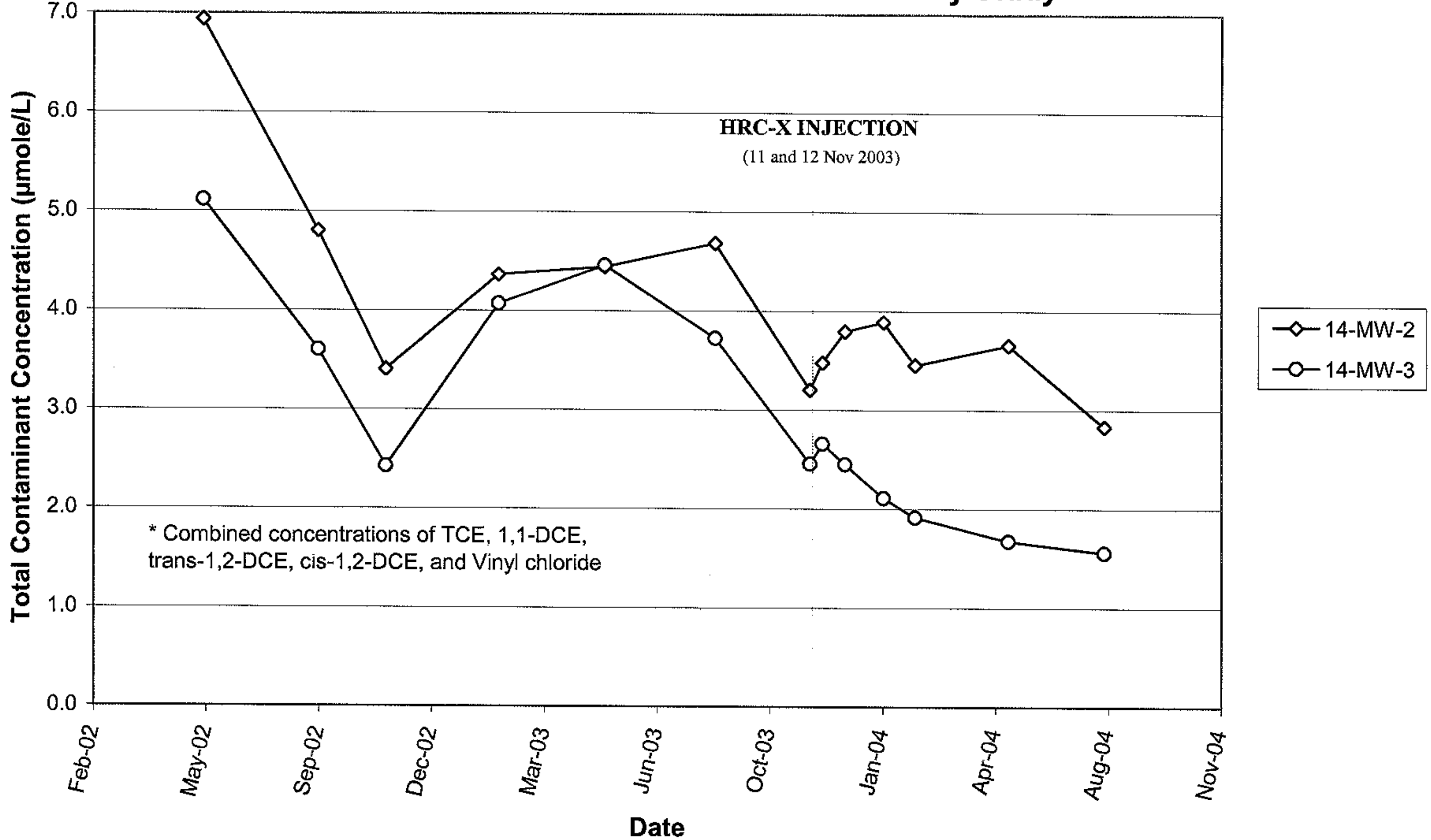


Figure 7 - Total* Contaminant Concentrations for Wells 14-MW-2 (440 feet upgradient, deep screen) and 14-MW-3 (10 feet downgradient, deep screen) Site 13 Cluster Groundwater Treatability Study



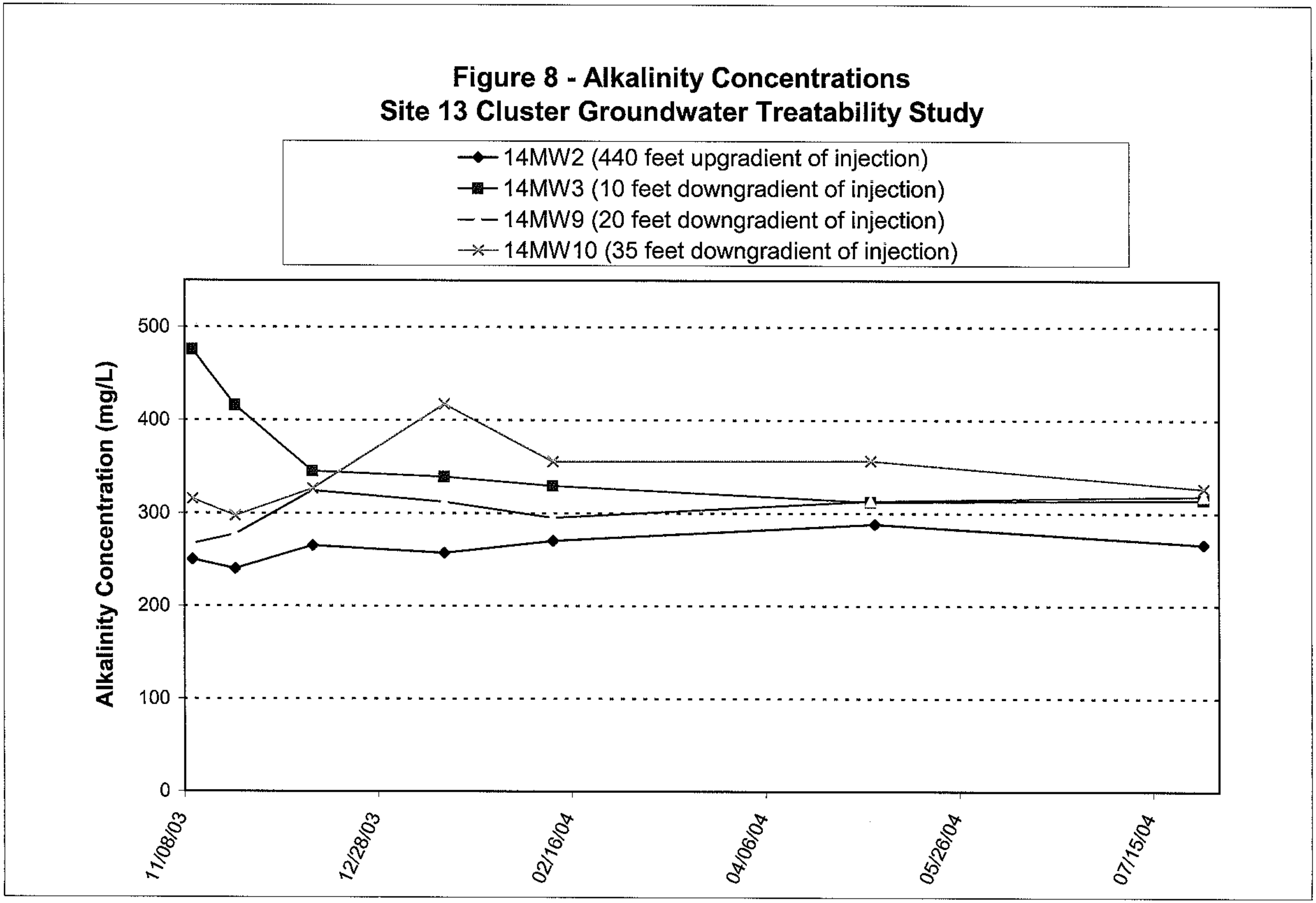


Figure 8 - Alkalinity Concentrations
Site 13 Cluster Groundwater Treatability Study
14MW2 (440 feet upgradient of injection)
14MW3 (10 feet downgradient of injection)
14MW9 (20 feet downgradient of injection)
14MW10 (35 feet downgradient of injection)
Alkalinity Concentration (mg/L)
0
100
200
300
400
500
11/08/03
12/28/03
02/16/04
04/06/04
05/26/04
07/15/04

Figure 9 - Methane Concentrations in Groundwater
Site 13 Cluster Groundwater Treatability Study

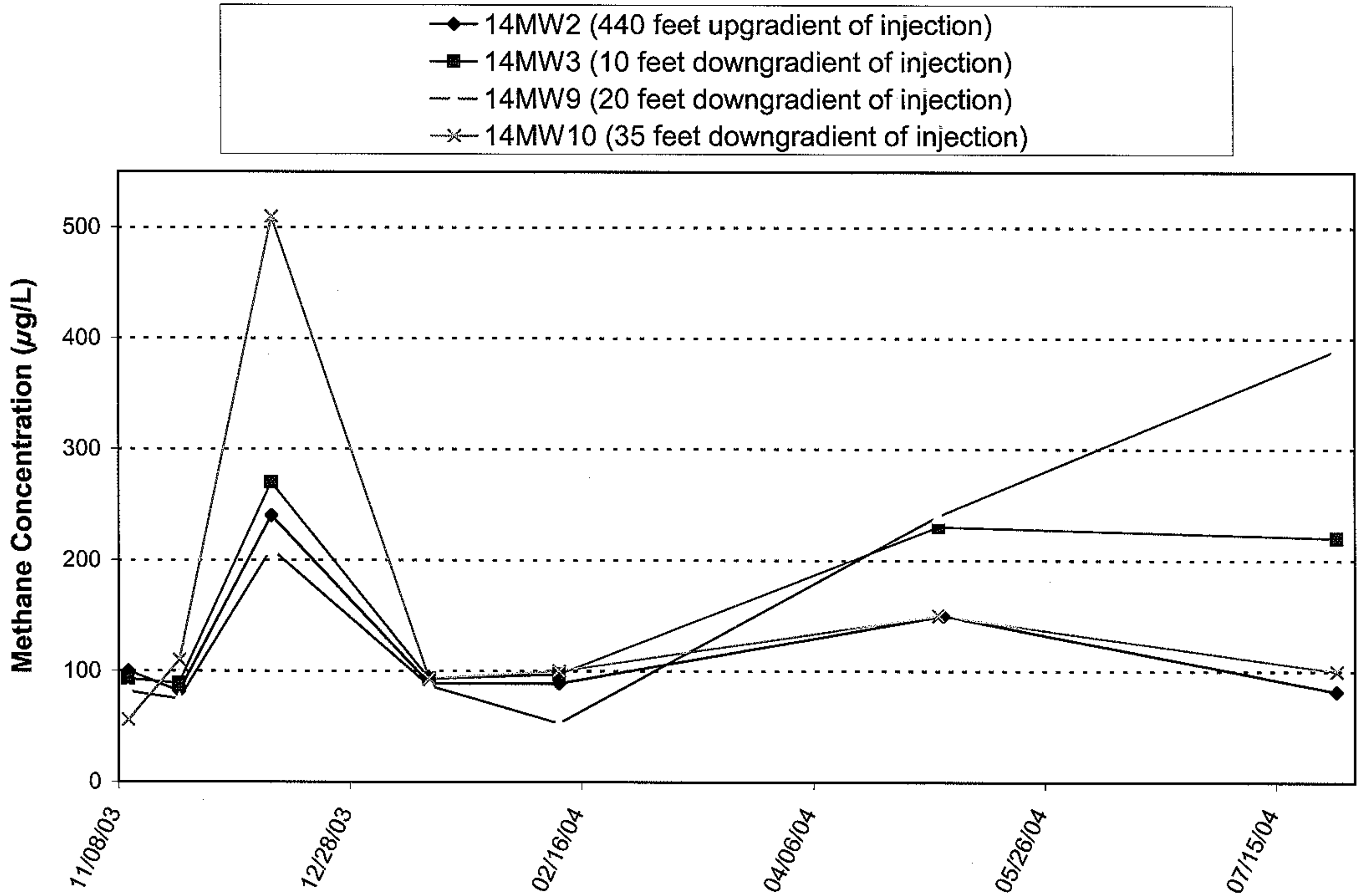
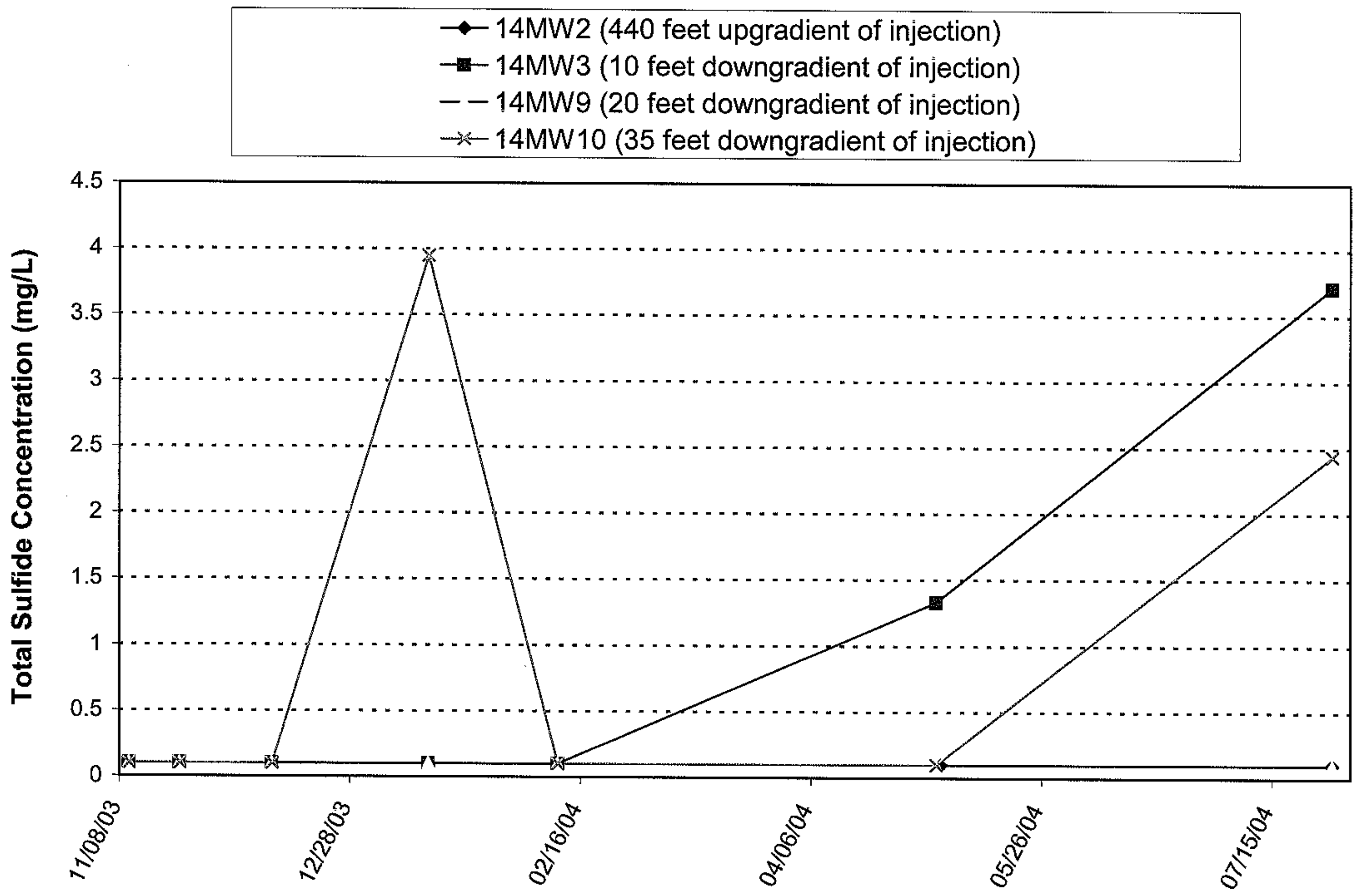


Figure 10 - Total Sulfide Concentrations
Site 13 Cluster Groundwater Treatability Study



TABLES

Table 1
Groundwater and ABRES-A Lake Elevations
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

			Groundwater Elevation (feet above msl)											
	Screen Interval (feet below TOC)		Summer-04		Spring-04		March-04		February-04		Winter-04		January-04	
Location		**Aquifer Zone**	**BGMP**	**Date**	**BGMP**	**Date**	**4-Month**	**Date**	**3-Month**	**Date**	**BGMP**	**Date**	**2-Month**	**Date**
ABRES-A Lake	N/A	N/A	NM	-	NM	-	46.84	17-Mar	NM	-	NM	-	NM	-
13-MW-1	8.1 - 18.6	Shallow	44.72	28-Jul	47.04	29-Apr	NM	-	47.61	13-Feb	48.25	28-Jan	NM	-
13-MW-2	13.6 - 33.6	Shallow	47.94	28-Jul	51.40	29-Apr	NM	-	51.30	13-Feb	52.10	28-Jan	NM	-
13-MW-3	10.2 - 25.2	Shallow	65.98	28-Jul	70.27	29-Apr	NM	-	73.49	3-Mar	73.25	28-Jan	NM	-
13-MW-6	42.9 - 52.9	Deep	47.93	28-Jul	51.34	29-Apr	NM		51.23	13-Feb	52.02	28-Jan	NM	-
13-MW-7	44.6 - 54.6	Deep	44.69	28-Jul	46.21	29-Apr	NM		47.57	13-Feb	48.53	28-Jan	NM	-
13-MW-8	7.02 - 17.02	Shallow	75.09	28-Jul	79.18	29-Apr	NM	-	83.23	11-Feb	85.70	28-Jan	86.15	14-Jan
14-MW-1	13.6 - 24.1	Shallow	43.48	28-Jul	48.32	29-Apr	46.37	17-Mar	47.14	13-Feb	47.79	28-Jan	NM	-
14-MW-2	66.4 - 76.4	Deep	43.28	28-Jul	45.21	29-Apr	46.27	17-Mar	47.05	11-Feb	47.72	28-Jan	48.48	14-Jan
14-MW-3	139.5 - 149.5	Deep	39.90	28-Jul	41.49	29-Apr	42.21	17-Mar	42.98	11-Feb	43.51	28-Jan	44.20	14-Jan
14-MW-4	104.6 - 114.6	Deep	35.15	28-Jul	36.77	29-Apr	NM	-	38.19	16-Feb	38.62	28-Jan	NM	
14-MW-5	127.3 - 137.3	Deep	21.99	28-Jul	22.49	29-Apr	NM	-	22.61	13-Feb	22.86	28-Jan	NM	-
14-MW-6	91.9 - 101.9	Deep	31.88	28-Jul	33.19	29-Apr	NM	-	34.45	10-Feb	34.75	28-Jan	NM	-
14-MW-7	81.8 - 91.8	Middle	31.77	28-Jul	33.11	29-Apr	NM	-	34.33	13-Feb	34.63	28-Jan	NM	-
14-MW-8	77.8 - 117.8	Middle	22.10	28-Jul	22.51	29-Apr	NM	-	22.84	13-Feb	23.02	28-Jan	NM	-
14-MW-9	102.1 - 122.1	Shallow	36.52	28-Jul	38.31	29-Apr	39.28	17-Mar	40.41	11-Feb	40.94	28-Jan	41.27	14-Jan
14-MW-10	132.0 - 147.0	Deep	38.40	28-Jul	39.97	29-Apr	40.73	17-Mar	41.51	11-Feb	42.00	28-Jan	42.78	14-Jan

Definitions:

ABRES-A Lake - Lake elevation, as measured from TOC of 14-MW-1
BGMP - Basewide Groundwater Monitoring Program
msl - mean sea level
N/A - not applicable
NM - not measured
TOC - top of well casing

Table 2
HRC-X Product Injection Schedule
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Injection Well ID	Screen Length (ft)	Primer Mass (lb)	HRC-X Mass (lb)	Total Mass (lb)
14-INJ-1	20	68	378	446
14-INJ-2	25	85	473	558
14-INJ-3	20	68	378	446
14-INJ-4	25	85	473	558
14-INJ-5	10	34	360	394
14-INJ-6	10	17	270	287
TOTAL	**110**	**357**	**2,332**	**2,689**

Definitions:

ft - feet
lb - pound

Table 3
Summary of Groundwater Analytical Results for Key VOCs
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Well		14-MW-2		14-MW-2		14-MW-2		14-MW-2		14-MW-2		14-MW-2	
Sample ID		V14MW2		V14MW2		V14MW2		V14MW2		V14MW2M		V14MW2	
Collection Date		Spring 02		Summer 02		Fall 02		Winter 03		Spring 03		Summer 03	
	Molecular Weight	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)
Analyte													
TCE	131.39	<0.5	<0.004	<0.5	<0.004	<0.5	<0.004	<0.5	<0.004	<0.18	<0.001	<0.18	<0.001
1,1-DCE	96.94	3.8	0.039	2.0	0.021	1.1	0.011	1.5	0.015	1.90	0.020	<0.32	NA
trans-1,2-DCE	96.94	10	0.10	5.3	0.055	5.2	0.054	4.4	0.045	4.16	0.043	4.4	0.045
cis-1,2-DCE	96.94	650	6.71	450	4.64	320	3.30	410	4.23	410	4.23	440	4.54
Vinyl chloride	62.50	5.6	0.090	5.0	0.080	2.4	0.038	4.2	0.067	9.33	0.149	6.1	0.10
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03
Total (µmole/L)			**6.94**		**4.80**		**3.40**		**4.36**		**4.44**		**4.68**

Well		14-MW-2		14-MW-2		14-MW-2		14-MW-2		14-MW-2		14-MW-2		14-MW-2	
Sample ID		V14MW2M		V14MW2		V14MW2		V14MW2		V14MW2		V14MW2		V14MW2	
Collection Date		10-Nov-03		21-Nov-03		11-Dec-03		14-Jan-04		11-Feb-04		04-May-04		28-Jul-04	
	Molecular Weight	Baseline (µg/L)	Baseline (µmole/L)	10 Days (µg/L)	10 Days (µmole/L)	1 Month (µg/L)	1 Month (µmole/L)	2 Months (µg/L)	2 Months (µmole/L)	3 Months (µg/L)	3 Months (µmole/L)	6 Months (µg/L)	6 Months (µmole/L)	9 Months (µg/L)	9 Months (µmole/L)
Analyte															
TCE	131.39	9.71	0.074	<0.32	<0.003	<0.1	<0.001	<0.14	<0.001	<0.32	<0.003	<0.2	<0.002	<0.2	<0.002
1,1-DCE	96.94	1.72	0.018	2.01	0.021	1.95	0.020	1.59	0.016	1.29	0.013	1.3	0.013	1	0.010
trans-1,2-DCE	96.94	3.69	0.038	4.65	0.048	12.13	0.125	11.56	0.119	3.84	0.040	4	0.041	3.5	0.036
cis-1,2-DCE	96.94	288	2.971	319.8	3.299	339.9	3.506	353.1	3.642	320	3.301	340	3.507	260	2.682
Vinyl chloride	62.50	4.63	0.074	5.03	0.080	6.96	0.111	4.90	0.078	4.33	0.069	4.5	0.072	5.3	0.085
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.6	<0.02	<0.6	<0.02
Total (µmole/L)			**3.17**		**3.45**		**3.76**		**3.86**		**3.42**		**3.63**		**2.81**

Table 3
Summary of Groundwater Analytical Results for Key VOCs
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Well		14-MW-3		14-MW-3		14-MW-3		14-MW-3		14-MW-3		14-MW-3	
Sample ID		V14MW3		V14MW3		V14MW3		V14MW3		V14MW3		V14MW3	
Collection Date		Spring 02		Summer 02		Fall 02		Winter 03		Spring 03		Summer 03	
	Molecular Weight	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)	(µg/L)	(µmole/L)
Analyte													
TCE	131.39	<0.5	<0.004	<0.5	<0.004	<0.5	<0.004	<0.5	<0.004	<0.18	<0.001	<0.18	<0.001
1,1-DCE	96.94	3.0	0.031	1.4	0.014	<0.5	NA	<0.5	NA	1.86	0.02	<0.32	<0.003
trans-1,2-DCE	96.94	21	0.22	9.4	0.10	8.1	0.084	9.3	0.10	9.45	0.097	9.4	0.10
cis-1,2-DCE	96.94	440	4.54	310	3.20	210	2.17	360	3.71	361	3.72	320	3.30
Vinyl chloride	62.50	20	0.32	18	0.29	11	0.18	16	0.26	38.3	0.613	20	0.32
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03
Total (µmole/L)			**5.11**		**3.60**		**2.43**		**4.07**		**4.45**		**3.72**

Well		14-MW-3		14-MW-3		14-MW-3		14-MW-3		14-MW-3		14-MW-3		14-MW-3	
Sample ID		V14MW3		V14MW3		V14MW3		V14MW3		V14MW3		V14MW3		V14MW3	
Collection Date		10-Nov-03		21-Nov-03		11-Dec-03		14-Jan-04		11-Feb-04		04-May-04		28-Jul-04	
	Molecular Weight	Baseline (µg/L)	Baseline (µmole/L)	10 Days (µg/L)	10 Days (µmole/L)	1 Month (µg/L)	1 Month (µmole/L)	2 Months (µg/L)	2 Months (µmole/L)	3 Months (µg/L)	3 Months (µmole/L)	6 Months (µg/L)	6 Months (µmole/L)	9 Months (µg/L)	9 Months (µmole/L)
Analyte															
TCE	131.39	<0.32	<0.003	<0.32	<0.002	<0.16	<0.001	<0.14	<0.001	<0.32	<0.002	<0.2	<0.002	<0.2	<0.002
1,1-DCE	96.94	1.23	0.013	1.46	0.015	1.01	0.010	0.86	0.009	0.65	0.007	0.34	0.004	0.22	0.002
trans-1,2-DCE	96.94	7.79	0.080	8.95	0.092	10.02	0.103	9.15	0.094	6.37	0.066	5.8	0.060	5.3	0.055
cis-1,2-DCE	96.94	204	2.104	220.2	2.27	201.9	2.08	172	1.77	160	1.65	93	0.96	59	0.61
Vinyl chloride	62.50	14.3	0.229	15.68	0.251	14.21	0.227	12.75	0.204	10.4	0.166	23	0.37	16	0.26
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	8	0.29	18	0.64
Total (µmole/L)			**2.43**		**2.63**		**2.42**		**2.08**		**1.89**		**1.39**		**0.92**

Table 3
Summary of Groundwater Analytical Results for Key VOCs
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Well		**14-MW-9**		**14-MW-9**		**14-MW-9**		**14-MW-9**		**14-MW-9**		**14-MW-9**		**14-MW-9**	
Sample ID		**V14MW9**		**V14MW9**		**V14MW9**		**V14MW9**		**V14MW9**		**V14MW9**		**V14MW9**	
Collection Date		**10-Nov-03**		**21-Nov-03**		**11-Dec-03**		**14-Jan-04**		**11-Feb-04**		**04-May-04**		**28-Jul-04**	
	Molecular Weight	**Baseline (µg/L)**	**Baseline (µmole/L)**	**10 Days (µg/L)**	**10 Days (µmole/L)**	**1 Month (µg/L)**	**1 Month (µmole/L)**	**2 Months (µg/L)**	**2 Months (µmole/L)**	**3 Months (µg/L)**	**3 Months (µmole/L)**	**6 Months (µg/L)**	**6 Months (µmole/L)**	**9 Months (µg/L)**	**9 Months (µmole/L)**
Analyte															
TCE	131.39	1.24	0.009	<0.32	<0.002	<0.1	<0.001	<0.14	<0.001	<0.32	<0.002	<0.2	<0.002	<0.2	<0.002
1,1-DCE	96.94	<0.41	<0.004	<0.41	<0.004	<0.15	<0.001	<0.14	<0.001	<0.41	<0.004	<0.2	<0.002	<0.2	<0.002
trans- 1,2-DCE	96.94	0.58	0.006	0.69	0.007	0.72	0.007	0.86	0.009	0.46	0.005	0.69	0.007	0.71	0.007
cis- 1,2-DCE	96.94	14.9	0.154	16.3	0.168	17.6	0.182	16.7	0.172	14.5	0.150	27	0.28	22	0.23
Vinyl chloride	62.50	3.53	0.056	3.82	0.061	5.29	0.085	3.68	0.059	2.54	0.041	12	0.19	15	0.24
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	1	0.04	1.1	0.039
Total (µmole/L)			**0.23**		**0.24**		**0.27**		**0.24**		**0.19**		**0.48**		**0.47**

Well		**14-MW-10**		**14-MW-10**		**14-MW-10**		**14-MW-10**		**14-MW-10**		**14-MW-10**		**14-MW-10**	
Sample ID		**V14MW10**		**V14MW10**		**V14MW10**		**V14MW10**		**V14MW10**		**V14MW10**		**V14MW10**	
Collection Date		**10-Nov-03**		**21-Nov-03**		**11-Dec-03**		**14-Jan-04**		**11-Feb-04**		**04-May-04**		**28-Jul-04**	
	Molecular Weight	**Baseline (µg/L)**	**Baseline (µmole/L)**	**10 Days (µg/L)**	**10 Days (µmole/L)**	**1 Month (µg/L)**	**1 Month (µmole/L)**	**2 Months (µg/L)**	**2 Months (µmole/L)**	**3 Months (µg/L)**	**3 Months (µmole/L)**	**6 Months (µg/L)**	**6 Months (µmole/L)**	**9 Months (µg/L)**	**9 Months (µmole/L)**
Analyte															
TCE	131.39	0.70	0.005	<0.32	<0.002	0.13	0.0010	<0.14	<0.001	<0.32	<0.002	<0.2	<0.002	<0.2	<0.002
1,1-DCE	96.94	1.72	0.018	2.12	0.022	1.67	0.017	0.86	0.009	0.71	0.007	0.44	0.005	0.39	0.004
trans-1,2-DCE	96.94	6.32	0.065	7.90	0.081	12.0	0.124	5.97	0.062	4.68	0.048	4.3	0.044	5	0.05
cis-1,2-DCE	96.94	289	2.98	340.70	3.51	360.0	3.71	179.70	1.854	203	2.09	120	1.24	110	1.13
Vinyl chloride	62.50	14.4	0.230	16.17	0.259	16.16	0.259	9.56	0.153	10.0	0.160	8.2	0.13	8.8	0.14
Ethene	28.05	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.9	<0.03	<0.6	<0.02	<0.6	<0.02
Total (µmole/L)			**3.30**		**3.88**		**4.11**		**2.08**		**2.31**		**1.42**		**1.33**

Notes:

DCE - dichloroethene
TCE - trichloroethene
µg/L - micrograms per liter
µmole/L - micromoles per liter
NC - No change, both baseline and 9 month values below laboratory detection limits

Table 4
VOCs in Groundwater
EPA Method SW8260B (µg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location				14-MW-2	14-MW-2	14-MW-2	14-MW-2	14-MW-2	14-MW-2*	14-MW-2*
Sample ID			CA	V14MW2M	V14MW2	V14MW2	V14MW2	V14MW2	V14MW2M	V14MW2M
Post HRC-X Injection Duration			Primary	Baseline	10-Days	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			MCL	10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	04-May-04	28-Jul-04
	MDL[1]	PQL[1]								
1,1,2-TCA	0.28	1.0	5	0.33 U g	0.33 U g	0.13 U g	0.16 U g	0.33 U g	0.25 J q	0.2 U g
1,1-DCE	0.32	1.0	6	1.72 g	2.01 g	1.95 J b	1.59 g	1.29 g	1.3 g	1 g
2-Hexanone	0.67	5.0	N/A	0.5 U g	0.5 U g	0.4 U g	1.1 U g	1.4 J q	2.5 U g	2.5 U g
4-Methyl-2-pentanone	0.46	10	N/A	0.6 U g	0.6 U g	0.1 U g	0.9 U g	1.2 J q	5 U g	5 U g
Acetone	0.78	10	N/A	1.5 U g	1.5 U g	29.5 U g	1.2 U g	1.5 U g	5 U g	5 U g
Benzene	0.07	0.4	1	0.13 U g	0.13 U g	0.07 U g	0.13 U g	0.13 U g	0.2 U g	0.2 U g
Carbon disulfide	0.48	1.0	N/A	0.48 U g	0.48 U g	0.08 U g	0.11 U g	0.48 U g	0.2 U g	0.2 U g
Chloromethane	0.32	1.0	N/A	0.34 U g	0.34 U g	6.74 U g	0.12 U g	0.34 U g	0.2 U g	0.2 U g
cis-1,2-DCE	0.21	1.0	6	288 g	319.80 g	339.90 J b	353.10 g	320 g	340 g	260 g
MEK (2-Butanone)	1.0	10	N/A	0.6 U g	0.6 U g	0.3 U g	0.9 U g	0.6 U g	5 U g	5 U g
Methylene chloride	0.09	1.0	5	0.13 U g	0.58 B J k, q	0.09 U g	0.13 U g	6.45 U g	0.5 U g	0.5 U g
trans-1,2-DCE	0.27	1.0	10	3.69 g	4.65 g	12.13 J b	11.56 g	3.84 g	4 g	3.5 g
TCE	0.18	1.0	5	9.71 g	0.32 U g	0.10 U g	0.14 U g	0.32 U g	0.2 U g	0.2 U g
Vinyl chloride	0.36	1.0	0.5	4.63 g	5.03 g	6.96 J b	4.90 g	4.33 g	4.5 g	5.3 g
All other target analytes	N/A	N/A	N/A	ND	ND	ND	ND	ND	ND	ND

Table 4
VOCs in Groundwater
EPA Method SW8260B (µg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location				14-MW-3	14-MW-3	14-MW-3	14-MW-3	14-MW-3	14-MW-3*	14-MW-3*
Sample ID			CA	V14MW3	V14MW3	V14MW3	V14MW3	V14MW3	V14MW3	V14MW3
Post HRC-X Injection Duration			Primary	Baseline	10-Days	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			MCL	10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	03-May-04	28-Jul-04
	MDL[1]	PQL[1]								
1,1,2-TCA	0.28	1.0	5	0.33 U g	0.33 U g	0.13 U g	0.16 U g	0.33 U g	0.2 U g	0.2 U g
1,1-DCE	0.32	1.0	6	1.23 g	1.46 g	1.01 g	0.86 J q	0.65 J q	0.34 J q	0.22 J q
2-Hexanone	0.67	5.0	N/A	0.5 U g	0.5 U g	0.4 U g	1.1 U g	0.5 U g	2.5 U g	2.5 U g
4-Methyl-2-pentanone	0.46	10	N/A	0.6 U g	0.6 U g	0.1 U g	0.9 U g	0.6 U g	5 U g	5 U g
Acetone	0.78	10	N/A	1.5 U g	1.5 U g	2.0 B J k, q	12.2 U g	1.5 U g	5 U g	5 U g
Benzene	0.07	0.4	1	0.13 U g	0.13 U g	0.07 U g	0.13 U g	0.13 U g	0.2 U g	0.2 U g
Carbon disulfide	0.48	1.0	N/A	0.48 U g	0.48 U g	0.08 U g	0.11 U g	0.48 U g	0.2 U g	0.2 U g
Chloromethane	0.32	1.0	N/A	0.34 U g	0.34 U g	3.37 U g	0.12 U g	0.34 U g	0.2 U g	0.2 U g
cis-1,2-DCE	0.21	1.0	6	204 g	220.20 g	201.90 g	172.00 g	160 g	93 g	59 g
MEK (2-Butanone)	1.0	10	N/A	0.6 U g	0.6 U g	0.3 U g	0.9 U g	0.6 U g	5 U g	11 g
Methylene chloride	0.09	1.0	5	0.13 U g	0.38 B J k, q	0.09 U g	0.13 U g	1.29 U g	0.5 U g	0.5 U g
trans-1,2-DCE	0.27	1.0	10	7.79 g	8.95 g	10.02 g	9.15 g	6.37 g	5.8 g	5.3 g
TCE	0.18	1.0	5	0.32 U g	0.32 U g	0.16 J q	0.14 U g	0.32 U g	0.2 U g	0.2 U g
Vinyl chloride	0.36	1.0	0.5	14.3 g	15.68 g	14.21 g	12.75 g	10.4 g	23 g	16 g
All other target analytes	N/A	N/A	N/A	ND	ND	ND	ND	ND	ND	ND

Table 4
VOCs in Groundwater
EPA Method SW8260B (µg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location Sample ID Post HRC-X Injection Duration Collection Date			CA Primary MCL	14-MW-9 V14MW9 Baseline 10-Nov-03	14-MW-9 V14MW9 10-Days 21-Nov-03	14-MW-9 V14MW9 1 Month 11-Dec-03	14-MW-9 V14MW9 2 Months 14-Jan-04	14-MW-9 V14MW9 3 Months 11-Feb-04	14-MW-9* V14MW9 6 Months 03-May-04	14-MW-9* V14MW9 9 Months 28-Jul-04
	MDL[1]	PQL[1]								
1,1,2-TCA	0.28	1.0	5	0.33 U g	0.33 U g	0.13 U g	0.16 U g	0.33 U g	0.2 U g	0.2 U g
1,1-DCE	0.32	1.0	6	0.41 U g	0.41 U g	0.15 U g	0.14 U g	0.41 U g	0.2 U g	0.2 U g
2-Hexanone	0.67	5.0	N/A	0.5 U g	0.5 U g	0.4 U g	1.1 U g	0.5 U g	2.5 U g	2.5 U g
4-Methyl-2-pentanone	0.46	10	N/A	0.6 U g	0.6 U g	0.1 U g	0.9 U g	0.6 U g	5 U g	5 U g
Acetone	0.78	10	N/A	2.6 J q	1.5 U g	0.7 U g	1.8 B J k, q	1.5 U g	5 U g	5 U g
Benzene	0.07	0.4	1	0.33 J q	0.33 J q	0.30 J q	0.35 J q	0.19 J q	0.2 U g	0.2 U g
Carbon disulfide	0.48	1.0	N/A	0.48 U g	0.48 U g	0.08 U g	0.12 J q	0.48 U g	0.2 U g	0.2 U g
Chloromethane	0.32	1.0	N/A	0.34 U g	0.34 U g	0.19 U g	0.12 U g	0.34 U g	0.2 U g	0.2 U g
cis-1,2-DCE	0.21	1.0	6	14.9 g	16.25 g	17.55 g	16.68 g	14.5 g	27 g	22 g
MEK (2-Butanone)	1.0	10	N/A	0.6 U g	0.6 U g	0.3 U g	0.9 U g	0.6 U g	5 U g	5 U g
Methylene chloride	0.09	1.0	5	0.13 U g	0.38 B J k, q	0.09 U g	0.13 U g	0.13 U g	0.5 U g	0.5 U g
trans-1,2-DCE	0.27	1.0	10	0.58 g	0.69 J q	0.72 J q	0.86 J q	0.46 J q	0.69 J q	0.71 J q
TCE	0.18	1.0	5	1.24 g	0.32 U g	0.10 U g	0.14 U g	0.32 U g	0.2 U g	0.2 U g
Vinyl chloride	0.36	1.0	0.5	3.53 g	3.82 g	5.29 g	3.68 g	2.54 g	12 g	15 g
All other target analytes	N/A	N/A	N/A	ND	ND	ND	ND	ND	ND	ND

Table 4
VOCs in Groundwater
EPA Method SW8260B (µg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location				14-MW-10	14-MW-10	14-MW-10	14-MW-10	14-MW-10	14-MW-10*	14-MW-10*
Sample ID			CA	V14MW10	V14MW10	V14MW10	V14MW10	V14MW10	V14MW10	V14MW10
Post HRC-X Injection Duration			Primary	Baseline	10-Days	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			MCL	10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	03-May-04	28-Jul-04
	MDL[1]	PQL[1]								
1,1,2-TCA	0.28	1.0	5	0.33 U g	0.33 U g	0.13 U g	0.16 U g	0.33 U g	0.2 U g	0.2 U g
1,1-DCE	0.32	1.0	6	1.72 g	2.12 g	1.67 g	0.86 J q	0.71 J q	0.44 J q	0.39 J q
2-Hexanone	0.67	5.0	N/A	0.5 U g	1.2 J q	0.4 U g	1.1 U g	0.5 U g	2.5 U g	2.5 U g
4-Methyl-2-pentanone	0.46	10	N/A	0.6 U g	1.1 J q	0.1 U g	0.9 U g	0.6 U g	5 U g	5 U g
Acetone	0.78	10	N/A	45.1 J q	73.8 U g	29.5 U g	9.9 B J k, q	9.9 J q	5 U g	5 U g
Benzene	0.07	0.4	1	0.13 U g	0.13 U g	0.07 U g	0.13 U g	0.13 U g	0.2 U g	0.2 U g
Carbon disulfide	0.48	1.0	N/A	0.48 U g	60.90 g	0.08 U g	0.11 U g	20.6 g	0.2 U g	0.26 J q
Chloromethane	0.32	1.0	N/A	0.34 U g	0.34 U g	9.74 U g	0.12 U g	0.34 U g	0.2 U g	0.2 U g
cis-1,2-DCE	0.21	1.0	6	289 g	340.70 g	360.40 g	179.70 g	203 g	120 g	110 g
MEK (2-Butanone)	1.0	10	N/A	0.6 U g	0.6 U g	0.3 U g	68.1 g	43.7 g	14 g	23 g
Methylene chloride	0.09	1.0	5	0.13 U g	0.39 B J k, q	0.09 U g	0.13 U g	0.13 U g	0.5 U g	0.5 U g
trans-1,2-DCE	0.27	1.0	10	6.32 g	7.90 g	12.01 g	5.97 g	4.68 g	4.3 g	5 g
TCE	0.18	1.0	5	0.70 J q	0.32 U g	0.13 J q	0.14 U g	0.32 U g	0.2 U g	0.2 U g
Vinyl chloride	0.36	1.0	0.5	14.4 g	16.17 g	16.16 g	9.56 g	10.0 g	8.2 g	8.8 g
All other target analytes	N/A	N/A	N/A	ND	ND	ND	ND	ND	ND	ND g

Table 4
VOCs in Groundwater
EPA Method SW8260B (µg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Data Validity Qualifiers:

B - The sample result is less than 5 times (10 times for common organic laboratory contaminants) the blank contamination. The result is considered not to have originated from the environmental sample, because cross-contamination is suspected.

J - The analyte was positively identified and the result is usable; however, the analyte concentration is an estimated value.

U - The analyte was not detected at or above the MDL.

Data Validity Comments:

b - The surrogate spike recovery was outside quality control criteria.
g - The data met prescribed criteria as detailed in the QAPP.
k - The analyte was found in a field blank.
q - The analyte detection was below the PQL.

Definitions:

DCE dichloroethene
HRC-X Hydrogen Release Compound - Extended Release Formula
µg/L - micrograms per liter
MCL - maximum contaminant level
MDL - Method detection limit for Columbia Analytical.
MEK - methyl ethyl ketone
N/A - not applicable
ND - not detected; result is less than the MDL
PQL Practical quantitation limit for Columbia Analytical.
QAPP Quality Assurance Project Plan
SAP - Sampling and Analysis Plan
TCA - trichloroethane
TCE - trichloroethene
VOC - volatile organic compound

Notes:

Six, nine, and twelve month sample analyses performed by EMAX Laboratories.

1 - Values from SAP Addendum (U.S. Air Force 2000a). The 6-, 9-, and 12-month MDL and PQL values from QAPP Addendum (U.S. Air Force 2004).

* - MDL and PQL values vary from those shown on table; the 6-, 9-, and 12-month MDL and PQL values will be provided in the Spring, Summer, and Fall 2004 BGMP Reports.

Table 5
Results for Metabolic Acids Analysis (mg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location		**14-MW-2**	**14-MW-2**	**14-MW-2**	**14-MW-2**	**14-MW-2**	**14-MW-2***	**14-MW-2***
Sample ID		**V14MW2M**	**V14MW2**	**V14MW2**	**V14MW2**	**V14MW2**	**V14MW2M**	**V14MW2M**
Sampling round (after HRC-X Injection)		**Baseline**	**10-Days**	**1 Month**	**2 Months**	**3 Months**	**6 Months**	**9 Months**
Collection Date		**10-Nov-03**	**21-Nov-03**	**11-Dec-03**	**14-Jan-04**	**11-Feb-04**	**04-May-04**	**28-Jul-04**
	MRL							
Acetic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	0.327 J q	1.62 g
Butyric Acid	0.5	NA	NA	NA	<0.5	<0.5	NA	<0.25 U g
Lactic Acid	0.5	<12.5	<12.5	<10	<5	<10	<0.25 U g	<0.25 U g
Propionic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	<0.25 U g	<0.25 U g
Pyruvic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	<0.25 U g	<0.25 U g

Sample Location		**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3***	**14-MW-3***
Sample ID		**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**
Sampling round (after HRC-X Injection)		**Baseline**	**10-Days**	**1 Month**	**2 Months**	**3 Months**	**6 Months**	**9 Months**
Collection Date		**10-Nov-03**	**21-Nov-03**	**11-Dec-03**	**14-Jan-04**	**11-Feb-04**	**03-May-04**	**28-Jul-04**
	MRL							
Acetic Acid	0.5	<10	<12.5	<10	<0.5	<0.5	4.63 g	34.2 g
Butyric Acid	0.5	NA	NA	NA	<0.5	<0.5	NA	<0.25 U g
Lactic Acid	0.5	<10	<12.5	<10	<5	<10	<0.25 U g	<0.25 U g
Propionic Acid	0.5	<10	<12.5	<10	<0.5	<0.5	0.669 g	1.76 g
Pyruvic Acid	0.5	<10	<12.5	<10	<0.5	<0.5	<0.25 U g	<0.25 U g

Table 5
Results for Metabolic Acids Analysis (mg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sample Location		**14-MW-9**	**14-MW-9**	**14-MW-9**	**14-MW-9**	**14-MW-9**	**14-MW-9***	**14-MW-9***
Sample ID		**V14MW9**	**V14MW9**	**V14MW9**	**V14MW9**	**V14MW9**	**V14MW9**	**V14MW9**
Sampling round (after HRC-X Injection)		**Baseline**	**10-Days**	**1 Month**	**2 Months**	**3 Months**	**6 Months**	**9 Months**
Collection Date		**10-Nov-03**	**21-Nov-03**	**11-Dec-03**	**14-Jan-04**	**11-Feb-04**	**03-May-04**	**28-Jul-04**
	MRL							
Acetic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	1.58 g	3.97 g
Butyric Acid	0.5	NA	NA	NA	<0.5	<0.5	NA	<0.25 U g
Lactic Acid	0.5	<12.5	<12.5	<10	<5	<10	<0.25 U g	<0.25 U g
Propionic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	<0.25 U g	<0.25 U g
Pyruvic Acid	0.5	<12.5	<12.5	<10	<0.5	<0.5	<0.25 U g	<0.25 U g

Sample Location		**14-MW-10**	**14-MW-10**	**14-MW-10**	**14-MW-10**	**14-MW-10**	**14-MW-10***	**14-MW-10***
Sample ID		**V14MW10**	**V14MW10**	**V14MW10**	**V14MW10**	**V14MW10**	**V14MW10**	**V14MW10**
Sampling round (after HRC-X Injection)		**Baseline**	**10-Days**	**1 Month**	**2 Months**	**3 Months**	**6 Months**	**9 Months**
Collection Date		**10-Nov-03**	**21-Nov-03**	**11-Dec-03**	**14-Jan-04**	**11-Feb-04**	**03-May-04**	**28-Jul-04**
	MRL							
Acetic Acid	0.5	<12.5	<12.5	<10	47	<0.5	2.52 g	6.37 g
Butyric Acid	0.5	NA	NA	NA	<25	<0.5	NA	<0.25 U g
Lactic Acid	0.5	<12.5	<12.5	<10	73	<10	<0.25 g	<0.25 U g
Propionic Acid	0.5	<12.5	<12.5	<10	55	1.7	0.574 J f	1.49 g
Pyruvic Acid	0.5	<12.5	<12.5	<10	<25	<0.5	<0.25 U g	<0.25 U g

Table 5
Results for Metabolic Acids Analysis (mg/L)
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Data Validity Qualifiers:

U - The analyte was not detected at or above the MDL.
J - The analyte was positively identified and the result is usable; however, the analyte concentration is an estimated value.

Data Validity Comments:

f - The duplicate/replicate sample's relative percent difference was outside the control limit.
g - The data met prescribed criteria as detailed in the QAPP.
q - The analyte detection was below the PQL.

Definitions:

MDL - method detection limit
MRL - Method reporting limit for American Analytics.
mg/L - milligrams per liter
NA - not analyzed
PQL - practical quantitation limit
QAPP - Quality Assurance Project Plan

Notes:

Six and nine month sample analyses performed by EMAX Laboratories.
* - MDL and PQL values vary from the MRL shown on table; these values will be provided in the Spring 2004 BGMP Report.

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sampling Location			**13-MW-8**	**13-MW-8**	**13-MW-8**	**13-MW-8***
Sample ID			**V13MW8**	**V13MW8**	**V13MW8**	**V13MW8**
Sampling round (after HRC-X Injection)			**10-Day**	**1 Month**	**3 Months**	**6 Months**
Collection Date			**21-Nov-03**	**14-Jan-04**	**11-Feb-04**	**04-May-04**
Laboratory Parameters (mg/L)	**MDL[1]**	**PQL[1]**				
Chloride	0.10	0.2	660 g	770 g	465 g	506 g
Sulfate	0.09	1.0	459 g	637 g	354 g	438 g
Alkalinity, total (as $CaCO_3$)	2.5	5.0	315 g	172 g	125 g	255 g
Nitrogen as nitrate + nitrite	0.02	0.1	0.05 U g	0.979 g	0.05 U g	0.02 U g
Total sulfide	0.1	1.0	0.1 U g	0.1 U g	0.1 U g	0.1 U g
Total organic carbon	1.0	5.0	12.9 g	13.3 J c	11.6 J e	13.9 g
Laboratory Parameters (µg/L)						
Ethane	0.8	2.0	0.8 U g	0.8 U g	0.8 U g	0.6 U g
Ethene	0.9	2.0	0.9 U g	0.9 U g	0.9 U g	0.6 U g
Methane	0.6	2.0	8.3 g	0.6 U g	13 g	5.7 g
Field Parameters[2]:						
Temperature (°Celsius)	N/A	N/A	15.53	11.71	10.83	15.65
Conductivity (µmhos/cm)	N/A	N/A	2,506	2,512	2,468	2,250
pH	N/A	N/A	6.80	7.18	6.76	7.10
Turbidity (NTUs)	N/A	N/A	4.43	0.52	1.04	0.54
Dissolved oxygen (mg/L)	N/A	N/A	20.57	3.36	0.95	0.80
Oxidation/reduction potential (mV)	N/A	N/A	105.9	140.6	-144	60.8
Fe II (mg/L)	N/A	N/A	0.0	0.0	0.0	0.0

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sampling Location			14-MW-2	14-MW-2	14-MW-2	14-MW-2	14-MW-2	14-MW-2*	14-MW-2*
Sample ID			V14MW2M	V14MW2	V14MW2	V14MW2	V14MW2	V14MW2M	V14MW2M
Sampling round (after HRC-X Injection)			Baseline	10-Day	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	04-May-04	28-Jul-04
Laboratory Parameters (mg/L)	MDL[1]	PQL[1]							
Chloride	0.10	0.2	535 g	328 g	351 g	374 g	348 g	329 g	395 g
Sulfate	0.09	1.0	244 g	222 g	224 g	235 g	197 g	197 g	203 g
Alkalinity, total (as $CaCO_3$)	2.5	5.0	250 g	240 g	265 g	257 g	270 g	288 g	266 g
Nitrogen as nitrate + nitrite	0.02	0.1	0.3 g	358 g	0.168 g	0.284 g	0.05 U g	0.02 U g	0.02 U g
Total sulfide	0.1	1.0	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g
Total organic carbon	1.0	5.0	14.1 g	14.5 g	13.8 g	14.2 J c	14 g	14.2 g	13.2 g
Laboratory Parameters (µg/L)									
Ethane	0.8	2.0	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.6 U g	0.6 U g
Ethene	0.9	2.0	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.6 U g	0.6 U g
Methane	0.6	2.0	100 g	82 g	240 g	89 g	89 g	150 g	82 g
Field Parameters[2]:									
Temperature (°Celsius)	N/A	N/A	16.54	16.27	15.34	15.27	15.65	17.08	17.10
Conductivity (µmhos/cm)	N/A	N/A	1,860	1,540	1,355	1,540	1,630	1,691	1,607
pH	N/A	N/A	7.02	7.20	7.50	7.35	6.77	NR	7.44
Turbidity (NTUs)	N/A	N/A	0.97	0.77	0.56	6.43	2.47	1.17	0.64
Dissolved oxygen (mg/L)	N/A	N/A	2.44	11.66	2.26	0.44	0.00	5.25	1.46
Oxidation/reduction potential (mV)	N/A	N/A	-99	-103.3	-119.4	-181.3	-102	-107	-260.7
Fe II (mg/L)	N/A	N/A	6.0	6.0	7	7.0	6.0	8.0	7

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sampling Location			**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3**	**14-MW-3***	**14-MW-3***
Sample ID			**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**	**V14MW3**
Sampling round (after HRC-X Injection)			**Baseline**	**10-Day**	**1 Month**	**2 Months**	**3 Months**	**6 Months**	**9 Months**
Collection Date			**10-Nov-03**	**21-Nov-03**	**11-Dec-03**	**14-Jan-04**	**11-Feb-04**	**03-May-04**	**28-Jul-04**
Laboratory Parameters (mg/L)	**MDL[1]**	**PQL[1]**							
Chloride	0.10	0.2	301 g	323 g	334 g	321 g	300 g	277 g	361 g
Sulfate	0.09	1.0	227 g	230 g	240 g	215 g	203 g	135 g	97.1 g
Alkalinity, total (as $CaCO_3$)	2.5	5.0	314 g	312 g	329 g	339 g	345 g	416 g	476 g
Nitrogen as nitrate + nitrite	0.02	0.1	0.228 g	0.309 g	0.218 g	0.298 g	0.05 U g	0.02 U g	0.021 J q
Total sulfide	0.1	1.0	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g	1.33 g	3.72 g
Total organic carbon	1.0	5.0	11.4 g	12.2 g	17.2 g	11.7 J c	12.7 g	12.6 g	24.2 g
Laboratory Parameters (µg/L)									
Ethane	0.8	2.0	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.6 U g	0.6 U g
Ethene	0.9	2.0	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.9 U g	8 g	18 g
Methane	0.6	2.0	93 g	89 g	270 g	93 g	97 g	230 g	220 g
Field Parameters[2]:									
Temperature (°Celsius)	N/A	N/A	16.79	10.59	15.99	16.16	16.20	17.19	17.94
Conductivity (µmhos/cm)	N/A	N/A	1,966	1,627	1,457	1,661	2,070	1,744	1,695
pH	N/A	N/A	7.06	7.31	7.30	7.35	6.77	7.11	7.44
Turbidity (NTUs)	N/A	N/A	6.5	1.94	1.46	8.20	1.62	1.17	2.54
Dissolved oxygen (mg/L)	N/A	N/A	0.13	13.29	3.64	4.58	-0.08	0.24	1.54
Oxidation/reduction potential (mV)	N/A	N/A	-126	-122.7	-128.2	-189.4	-131	-187	-351.7
Fe II (mg/L)	N/A	N/A	8	7.0	9	7	8.0	5.0	3

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sampling Location			14-MW-9	14-MW-9	14-MW-9	14-MW-9	14-MW-9	14-MW-9*	14-MW-9*
Sample ID			V14MW9	V14MW9	V14MW9	V14MW9	V14MW9	V14MW9	V14MW9
Sampling round (after HRC-X Injection)			Baseline	10-Day	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	03-May-04	28-Jul-04
Laboratory Parameters (mg/L)	MDL[1]	PQL[1]							
Chloride	0.10	0.2	414 g	376 g	431 g	484 g	406 g	371 g	440 g
Sulfate	0.09	1.0	206 g	193 g	210 g	212 g	194 g	176 g	164 g
Alkalinity, total (as $CaCO_3$)	2.5	5.0	267 g	277 g	324 g	312 g	295 g	313 g	318 g
Nitrogen as nitrate + nitrite	0.02	0.1	0.05 U g	0.05 U g	0.05 U g	0.154 g	0.05 U g	0.02 U g	0.02 U g
Total sulfide	0.1	1.0	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g	0.1 U g
Total organic carbon	1.0	5.0	18.3 g	19.2 g	18.9 g	19.1 J c	18.7 g	17.3 g	16.7 g
Laboratory Parameters (µg/L)									
Ethane	0.8	2.0	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.6 U g	0.6 U g
Ethene	0.9	2.0	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.9 U g	[illegible] J q	1.1 J q
Methane	0.6	2.0	82 g	75 g	210 g	87 g	53 g	240 g	390 g
Field Parameters[2]:									
Temperature (°Celsius)	N/A	N/A	17.95	16.53	15.63	16.03	15.63	16.57	18.73
Conductivity (µmhos/cm)	N/A	N/A	2,159	1,771	1,567	1,816	2,265	1,851	1,812
pH	N/A	N/A	7.15	7.45	7.48	7.50	6.88	7.07	7.28
Turbidity (NTUs)	N/A	N/A	4.72	2.33	0.80	2.61	0.34	0.81	1.04
Dissolved oxygen (mg/L)	N/A	N/A	2.87	12.98	4.08	3.24	0.15	0.40	1.93
Oxidation/reduction potential (mV)	N/A	N/A	45	-100.7	-112.5	-76.6	-7	-144	-67.9
Fe II (mg/L)	N/A	N/A	0.0	0.0	0.1	0.0	0.0	0.0	0.3

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Sampling Location			14-MW-10	14-MW-10	14-MW-10	14-MW-10	14-MW-10	14-MW-10*	14-MW-10*
Sample ID			V14MW10	V14MW10	V14MW10	V14MW10	V14MW10	V14MW10	V14MW10
Sampling round (after HRC-X Injection)			Baseline	10-Day	1 Month	2 Months	3 Months	6 Months	9 Months
Collection Date			10-Nov-03	21-Nov-03	11-Dec-03	14-Jan-04	11-Feb-04	03-May-04	28-Jul-04
Laboratory Parameters (mg/L)	MDL[1]	PQL[1]							
Chloride	0.10	0.2	278 g	290 g	281 g	323 g	305 g	294 g	339 g
Sulfate	0.09	1.0	178 g	179 g	178 g	180 g	175 g	216 g	210 g
Alkalinity, total (as $CaCO_3$)	2.5	5.0	315 g	297 g	326 g	417 g	355 g	356 g	326 g
Nitrogen as nitrate + nitrite	0.02	0.1	0.52 g	0.307 g	0.146 g	0.405 g	0.05 U g	0.02 U g	0.02 U g
Total sulfide	0.1	1.0	0.1 U g	0.1 U g	0.1 U g	3.95 g	0.1 U g	0.1 U g	2.44 g
Total organic carbon	1.0	5.0	12.8 g	14.6 g	14.2 g	73 J c	29.3 g	11.4 g	11.5 g
Laboratory Parameters (µg/L)									
Ethane	0.8	2.0	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.8 U g	0.6 U g	0.6 U g
Ethene	0.9	2.0	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.9 U g	0.6 U g	0.6 U g
Methane	0.6	2.0	56 g	110 g	510 g	93 g	100 g	150 g	100 g
Field Parameters[2]:									
Temperature (°Celsius)	N/A	N/A	17.42	16.18	16.13	16.25	15.82	16.64	17.32
Conductivity (µmhos/cm)	N/A	N/A	1,774	1,445	1,330	1,635	1,975	1,696	1,619
pH	N/A	N/A	7.13	7.38	7.38	7.58	6.69	7.78	7.24
Turbidity (NTUs)	N/A	N/A	8.38	4.92	0.89	3.26	2.07	3.21	2.37
Dissolved oxygen (mg/L)	N/A	N/A	2.39	11.21	3.56	0.33	0.07	8.84	1.63
Oxidation/reduction potential (mV)	N/A	N/A	-117	-119.2	-131	-231.8	-193	-215	-161.2
Fe II (mg/L)	N/A	N/A	7.5	5.0	6	5	6.0	8.0	6

Table 6
Water Quality Parameters
EPA Methods E300.0, E310.2, E353.2, E376.2, E415.1, and RSK175
IRP Site 13 Cluster Groundwater Treatability Study
Vandenberg AFB, California

Data Validity Qualifiers:

U	The analyte was not detected at or above the MDL.
J	The analyte was positively identified and the result is usable; however, the analyte concentration is an estimated value.

Data Validity Comments:

c	The matrix spike and/or matrix spike duplicate recoveries were outside control limits.
e	A holding time violation occurred.
g	The data met prescribed criteria as detailed in the QAPP.
q	The analyte detection was below the PQL.

Definitions:

$CaCO_3$	-	calcium carbonate
MDL	-	method detection limit
mg/L		milligrams per liter
µg/L		micrograms per liter
µmhos/cm		micromhos per centimeter
mV	-	millivolts
N/A	-	not applicable
NR	-	not recorded
NTU	-	nephelometric turbidity unit
ppm	-	practical quantitation limit
PQL	-	practical quantitation limit
QAPP		Quality Assurance Project Plan
SAP		Sampling and Analysis Plan

Notes:

Fe II units of mg/L are equivalent to units of ppm measured in the field.
Ph was not recorded at well 14-MW-2 during the 6 month sampling event due to the value being out of acceptable range.
Six, nine, and twelve month sample analyses performed by EMAX Laboratories.

1	Values from SAP Addendum (U.S. Air Force 2000a). The 6-, 9-, and 12-month MDL and PQL values from QAPP Addendum (U.S. Air Force 2004).
2	Field parameters measured within 30 minutes prior to sampling.
*	MDL and PQL values vary from those shown on table; the 6-, 9-, and 12- month MDL and PQL values are provided in the Spring and Summer 2004 BGMP Reports.

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A BORING LOGS AND WELL CONSTRUCTION DIAGRAMS

Tetra Tech, Inc.
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base
Log of Well No. 14-MW-9
Location: OU4, Site 14, approximately 890 ft southwest of Building 1794, west of Watt Road.

Date Started: 7/30/03	Completed: 8/1/03
Logged By: S. Serratore	Checked By: D. Springer, R.G. DS RG#6962
Drilled By: Ramon Zereda, BC2 Environmental Corp.	
Drilling Equipment: CME 95, 13" HSA	
Sampling Equipment: 2" I.D. Split Spoon	
GS Elev.: 130 ft above MSL	TD: 150 ft

4" PVC Blank Casing:	from	0 ft bgs to	98 ft bgs
4" Screening Casing:	from	98 ft bgs to	118 ft bgs
Bentonite/Cement Grout:	from	0 ft bgs to	91 ft bgs
Bentonite Transitional Seal:	from	91 ft bgs to	96 ft bgs
Sand Filter Pack:	from	96 ft bgs to	120 ft bgs

TOC Elev.: 132.82 ft above MSL

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
0	sand, dark yellowish brown (10YR 3/6), fine to medium-grained, subrounded, loose, dry, dune sand		SP					0.3/ 0.2	Start drilling 0751. PID readings taken from ambient borehole. Soil logged using cuttings.
5									
10	yellowish brown (10YR 5/6), dense, slightly moist							0.2/ 0.2	
15									
20									

90 ft. bgs Groundwater depth during drilling 90.81 ft. bgs Groundwater depth after well development on: 11/05/03

TC Number: A250-48

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Project: Vandenberg Air Force Base
Log of Well No 14-MW-9
Location: OU4, Site 14, approximately 890 ft southwest of Building 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
20	sand, yellowish brown (10YR 5/6), fine to medium-grained, subrounded, dense, slightly moist, dune sand								
25									
30								0.2/ 0 1	
35									
40								0.2/ 0.1	
45	Dark yellowish brown (10YR 4/4).								

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Project: Vandenberg Air Force Base
Log of Well No 14-MW-9

Location: OU4, Site 14, approximately 890 ft southwest of Building 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
45	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, subrounded, dense, slightly moist, dune sand		SP						
50								0.2/ 0.2	
55									
60								0.2/ 0.1	
65									Begin drilling with a 10" auger at 11:30. Drilling started at 65' on 7/31/03. Redrilled borehole.
70								0.2/ 0.2	

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Project: Vandenberg Air Force Base
Log of Well No. 14-MW-9

Location: OU4, Site 14, approximately 890 ft. southwest of Building 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
70	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, subrounded, dense, slightly moist, dune sand.		SP						
75									
80									
85									
90	brown (10YR 4/3), wet, some silt.							0.1/ 0.1	
95									

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Project: Vandenberg Air Force Base
Log of Well No 14-MW-9
Location: OU4, Site 14, approximately 890 ft. southwest of Building 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
95	sand, brown (10YR 4/3), fine to medium-grained, subrounded, dense, wet, some silt, dune sand		SP						
100	dark grayish brown (10YR 4/2)							0.1/ 0 1	
105									
110									Auger locking. Switch to 10" auger. Continued drilling at 11:35.
115									
120									

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Project: Vandenberg Air Force Base
Log of Well No. 14-MW-9

Location: OU4, Site 14, approximately 890 ft. southwest of Building 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
120	sand, dark grayish brown (10YR 4/2), fine to medium-grained, subrounded, dense, wet, some silt, dune sand		SP						
125									
130	Silty sand, very dark grayish brown (10YR 3/2), fine to medium grained, subrounded, dense, wet.		SM					0.1/ 0.1	
135									
140									
145	very dense.								

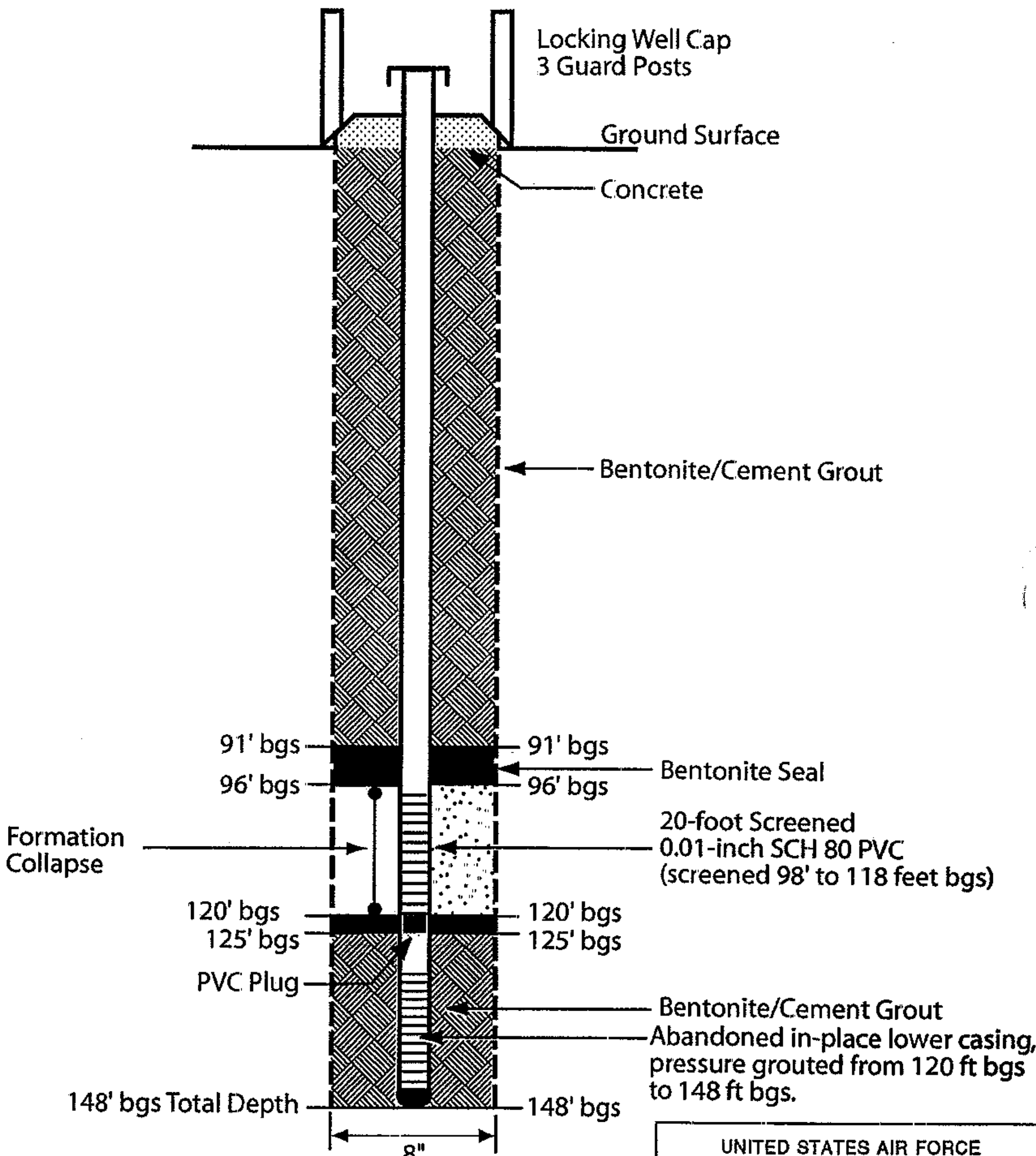
Tetra Tech, Inc
4213 State Street, Suite 100
Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base
Log of Well No 14-MW-9

Location: OU4, Site 14, approximately 890 ft southwest of Building 1794, west of Watt Road.

Depth (ft. bg)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
145	Silty sand, very dark grayish brown (10YR 3/2), fine to medium grained, subrounded, very dense, wet		SM						
	shale, dark grayish brown (10YR 4/2), hard, Monterey Formation		SHALE						
150									End drilling at 2015 on 7/31/03
155									
160									
165									
170									

4-inch Diameter SCH 80 PVC Monitoring Well



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

CONSTRUCTION FOR
MONITORING WELL
14-MW-9

TASK NO.	DATE	DRAWN BY	AI FILE NO.	FIGURE NO.
A250-48	9/10/03	RANDALL	G:\Irp-Restoration\ Ir-RI\Site13c Treatibility\ 3.2-3ProDesign 14-MW-9.ai	14-MW-9

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Date Started: 10/15/03	Completed: 10/21/03
Logged By: D. Fenity	Checked By: D. Springer, R. G. DJ RG#6962
Drilled By: D. Osterberg, Boart Longyear	
Drilling Equipment: Sonic 9"/8"	
Sampling Equipment: Sonic Sampler Bit - 5" continous core	
GS Elev.: 130 ft above MSL	TD: 148 ft

4 " PVC Bank Casing:	from	0	ft bgs to	129	ft bgs
4" Screened Casing:	from	129	ft bgs to	144	ft bgs
Bentonite/Cement Grout:	from	4	ft bgs to	119	ft bgs
Bentonite Transitional Seal:	from	119	ft bgs to	127	ft bgs
Sand Filter Pack:	from	127	ft bgs to	148	ft bgs

TOC Elev.: 133.85 ft above MSL

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
	sand, yellowish brown (10YR 5/6), fine to medium-grained, subrounded to subangular, poorly graded, dry, dune sand.		SP						0730 Begin drilling 10/15/03.
							100	0/0	
5								0/0	
								0/0	
10								0/0	
	fine-grained.								PID not functioning properly.
15									
	slightly moist.								
20									

98 ft. bgs. Groundwater depth during drilling 91.50 ft. bgs Groundwater depth after well development on: 11/4/03

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
20	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, subrounded to subangular, poorly graded, slightly moist, dune sand		SP				100		PID not functioning properly.
	yellowish brown (10YR 5/6)								
25	fine-grained								
	moist								
30	trace silt								
35									
40									
	no silt								

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs.)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
45	sand, yellowish brown (10YR 5/6), fine to medium-grained, subrounded to subangular, poorly graded, moist, dune sand.		SP				100		PID not functioning properly.
50									
	dark yellowish brown (10YR 4/4).								
55	dark yellowish brown (10YR 5/6).								
	dark yellowish brown (10YR 4/4), trace silt.								
60									
65									

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
70	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, subrounded to subangular, poorly graded, slightly moist, dune sand.		SP				100		PID not functioning properly.
75									
80	fine-grained.								
	little silt								
85									
	yellowish brown (10YR 5/6).								
90									
	moist.								

R:\Boring Logs\MWells\14... 4 of 7 11/20/03

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
95	sand, yellowish brown (10YR 5/6), fine to medium-grained, subrounded to subangular, poorly graded, moist, little silt, alluvium		SP				100		PID not functioning properly.
	wet.								Groundwater encountered at 98 ft bgs during drilling
100									
105									
110									
115									
									Bentonite transitional seal from 119 to 127 feet bgs.

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
120	sand, greenish black (2.5 GLEY2 10B), fine to medium-grained, subrounded, poorly graded, wet, little clay, alluvium		SP				100		PID not functioning properly.
125	clay, organic, bluish black (2.5 GLEY2 2.5/1), stiff to very stiff, organic odor, trace angular gravel (siltstone and chert), alluvium.		OH						4" PVC screened casing: 129 ft to 144 ft bgs.
130	sand, greenish black (2.5 GLEY1 2.5/1), fine to medium-grained, subrounded, poorly graded, wet, little angular gravel, alluvium. medium grained.		SP						
135	silty sand, black (7.5 YR 2.5/1), fine-grained, subrounded, poorly graded, wet, little angular gravel (siltstone <3 cm), alluvium. little clay.		SM						
140									
	shale, olive gray (5Y 5/2), weathered Monterey Shale.		SHALE						4" PVC Sump from 144 ft to 157 ft bgs.

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Santa Barbara, CA 93110-2847
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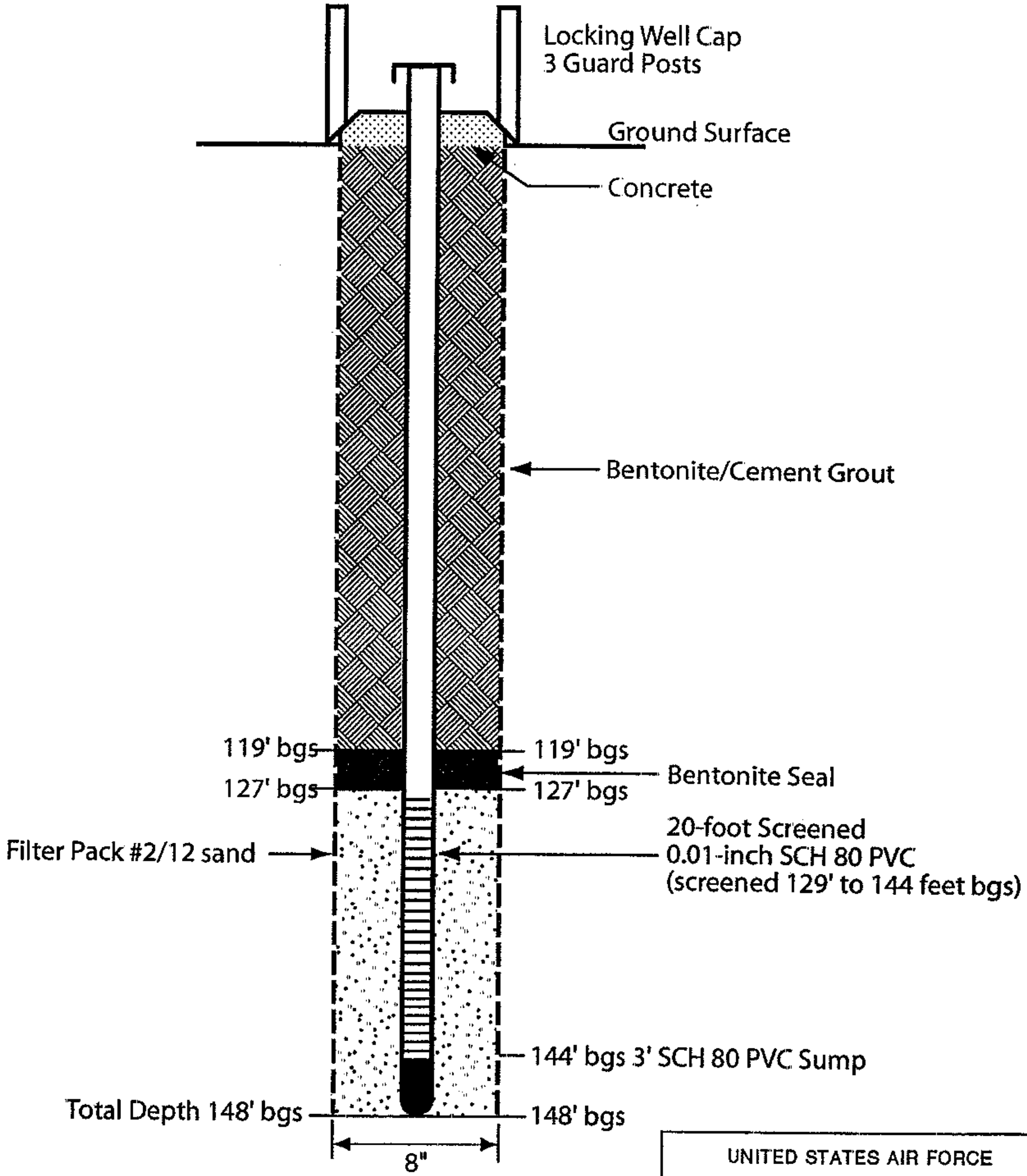
Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-MW-10

Location: OU4, Site 14, 15 feet downgradient of 14-MW-9

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
145	shale, olive gray (5Y 5/2), weathered Monterey Shale.		SHALE				100		PID not functioning properly. Bottom of well: 147 ft bgs. Total depth: 148 ft bgs.
150									
155									
160									
165									

4-inch Diameter SCH 80 PVC Monitoring Well



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

CONTRUCTION FOR
MONITORING WELL
14-MW-10

TASK NO.	DATE	DRAWN BY	AI FILE NO.	FIGURE NO.
A250-48	11/15/03	LOVE	G:\Irp-Restoration\ Ilr-RI\Site13c Treatibility\ 3.2-3ProDesign 14-MW-9.ai	14-MW-10

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

e Started: 10/25/03 Completed: 10/29/03

Logged By: D. Fenity Checked By: D. Springer, R. G.

Drilled By: D. Osterberg, Boart Longyear DF RG #6962

Drilling/Sampling Equipment: Sonic 9"/8"/ Sonic Sampler Bit - 5" continuous core.

GS Elev.: 130 ft above MSL TD: 157 ft

TOC Elev.: 134.05 ft above MSL

	Well					
2" PVC Bank Casing:	14-INJ-1:	from 0	ft bgs to	95	ft bgs
	14-INJ-2:	from 0	ft bgs to	125	ft bgs
2" Screened Casing:	14-INJ-1:	from 95	ft bgs to	115	ft bgs
	14-INJ-2:	from 127	ft bgs to	152	ft bgs
Bentonite/Cement Grout:	14-INJ-1:	from 0	ft bgs to	87	ft bgs
	14-INJ-2:	from 0	ft bgs to	87	ft bgs
Bentonite Transitional Seal:	14-INJ-1:	from 87	ft bgs to	92	ft bgs
	14-INJ-2:	from 120	ft bgs to	125	ft bgs
Sand Filter Pack:	14-INJ-1:	from 92	ft bgs to	120	ft bgs
	14-INJ-2:	from 125	ft bgs to	157	ft bgs
2" PVC Sump:	14-INJ-1:	from 115	ft bgs to	120	ft bgs
	14-INJ-2:	from 152	ft bgs to	157	ft bgs

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, dry, dune sand		SP				100		0755 Begin drilling. PID not functioning properly.
5									
10	slightly moist								
15	dark yellowish brown (10YR 4/4).								
	dark yellowish brown (10YR 4/6).								
20									

98 ft. bgs ▼ Groundwater depth during drilling. 91.80 ft. bgs ▽ Groundwater depth after well development on: 11/4/03

TC Number: A250-48

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Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
20	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, slightly moist, trace silt, dune sand		SP				100		PID not functioning properly
	fine to medium-grained, no silt								
25									
	trace silt								
30	no silt								
35	trace silt								
40									

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VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
45	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, slightly moist, trace silt, dune sand		SP				100		PID not functioning properly
	no silt								
55	fine-grained								
	dark yellowish brown (10YR 4/4), trace silt								
60	few silt								
	dark yellowish brown (10YR 4/6), no silt								
65									
	dark yellowish brown (10YR 4/4), trace silt								

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
70	sand, dark yellowish brown (10YR 4/6), fine-grained, poorly graded, subrounded to subangular, slightly moist, trace silt, dune sand.		SP				100		PID not functioning properly.
75									
80	dark yellowish brown (10YR 4/4).								
85	dark yellowish brown (10YR 3/4).								
	dark yellowish brown (10YR 4/6), no silt.								Bentonite transitional seal from 87 to 92 feet bgs.
90									

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 /14-INJ-2
Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs.)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
95	sand, dark yellowish brown (10YR 3/4), fine-grained, poorly graded, subrounded to subangular, slightly moist, no silt, dune sand		SP				100		PID not functioning properly.
	wet.								Groundwater encountered at 98 ft bgs during drilling.
100									Upper screened interval: 95 ft to 115 ft bgs.
105									
	trace silt.								
110	no silt.								
115	clay, organic, bluish black (2.5 GLEY2 10B), stiff to very stiff, organic odor, trace angular gravel (siltstone), trace fine-grained sand.		OH						14-INJ-1 2" PVC sump from 115 ft to 120 ft bgs.
	silty clay, organic black (7.5YR 2.5/1), soft, organic odor, little silt, trace fine sand, trace gastropod fragments, alluvium.		OL						

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Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2
Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Type	Percent Recovery	REMARKS
120	sandy silt, organic, brown (7.5YR 4/2), interbedded with black (7.5YR 2.5/1), fine-grained, trace gastropod fragments, trace clay, alluvium.	OL	100	PID not functioning properly. Bentonite transitional seal from 120 to 125 feet bgs
	peat, dark brown (2.5YR 3/3), soft, highly organic, few pine needles and gastropod fragments, some silt.	PT		
125	clay, organic, bluish black (2.5 GLEY2 10B), stiff to very stiff, organic odor, trace angular gravel (siltstone and chert), trace gastropod fragments, alluvium.	OH		
	silty sand, black (7.5YR 2.5/1), fine-grained, poorly graded, some silt, few angular gravel (siltstone), trace clay, alluvium.	SM		Lower screened interval: 127 ft to 152 ft bgs.
130				
	few clay.			
135	very dark gray (10YR 3/1), few angular gravel (Monterey Shale).			
140	clay, organic, bluish black (2.5 GLEY2 10B), soft, few silt, few fine-grained sand, alluvium.	OL		
	silty sand, black (7.5YR 2.5/1), fine-grained, poorly graded, subrounded to subangular, wet, some silt, trace angular gravel (Monterey Shale), alluvium.	SM		

Column headers also include: Material Symbol, Well Construction, Sample, Blow Counts per 6", PID (ppm) Amb/Smp.

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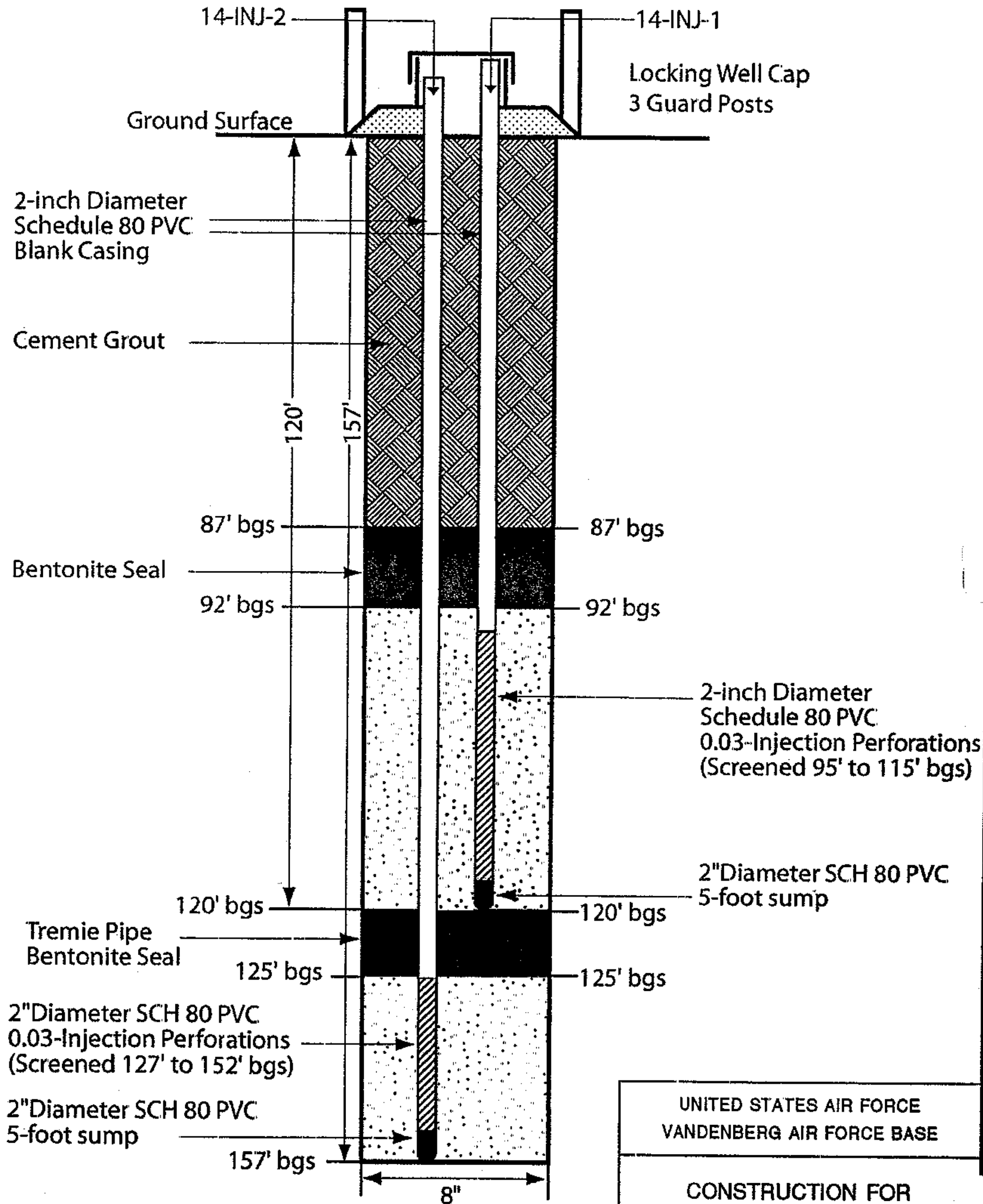
Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-1 / 14-INJ-2

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
145	sandy gravel, gray (10YR 5/1), medium-grained, poorly graded, subrounded, wet, some angular gravel, (Monterey Shale), alluvium. angular, little medium-grained sand, trace silt, weathered Monterey Shale		GP				100		PID not functioning properly
150									
	shale, olive gray (5Y 5/2), weathered, wet, Monterey Shale		SHALE						14-INJ-2 2" PVC sump from 152 ft to 157 ft bgs.
155									
									Total depth: 157 ft bgs.
160									
165									

2-inch Diameter SCH 80 PVC Injection Wells



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

CONSTRUCTION FOR
INJECTION WELLS
14-INJ-1/2

TASK NO.	DATE	DRAWN BY	AI FILE NO.	FIGURE NO.
A250-48	11/17/03	RANDALL	G:\Irp-Restoration\ Ilk-RI\Site13c Treatability\ ProDesign 14-inj-1-2.ai	14-INJ-1/2

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Date Started: 10/22/03 Completed: 10/29/03

Logged By: D Fenity Checked By: D Springer, R G.

Drilled By: D. Osterberg, Boart Longyear DF RG #6962

Drilling/Sampling Equipment: Sonic 9"/8"/ Sonic Sampler Bit - 5" continuous core.

GS Elev.: 130 ft above MSL TD: 160 ft

TOC Elev.: 134.01ft above MSL

Item	Well		From		To	
2" PVC Bank Casing:	14-INJ-3:	from	0	ft bgs to	95	ft bgs
	14-INJ-4:	from	0	ft bgs to	125	ft bgs
2" Screened Casing:	14-INJ-3:	from	97	ft bgs to	117	ft bgs
	14-INJ-4:	from	125	ft bgs to	150	ft bgs
Bentonite/Cement Grout:	14-INJ-3:	from	0	ft bgs to	87	ft bgs
	14-INJ-4:	from	0	ft bgs to	87	ft bgs
Bentonite Transitional Seal:	14-INJ-3:	from	87	ft bgs to	93	ft bgs
	14-INJ-4:	from	117	ft bgs to	123	ft bgs
Sand Filter Pack:	14-INJ-3:	from	93	ft bgs to	118	ft bgs
	14-INJ-4:	from	123	ft bgs to	160	ft bgs
2" PVC Sump:	14-INJ-3:	from	117	ft bgs to	122	ft bgs
	14-INJ-4:	from	150	ft bgs to	160	ft bgs

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
	sand, yellowish brown (10YR 5/6), fine to medium-grained, poorly graded, subrounded to subangular, dry, dune sand.		SP						0800 Begin drilling.
							100		PID not functioning properly due to heavy fog.
5									
10	dark yellowish brown (10YR 4/6).								
15	fine-grained.								
	fine to medium-grained, slightly moist.								
20									

97.5 ft. bgs ▼ Groundwater depth during drilling 89.90 ft. bgs ▽ Groundwater depth after well development on: 11/4/03

TC Number: A250-48

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Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
20	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, slightly moist, dune sand		SP				100		PID not functioning properly
25									
	yellowish brown (10YR 5/6)								
30									
35									
40	dark yellowish brown (10YR 4/4)								
	dark yellowish brown (10YR 5/6)								

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
45	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, slightly moist, dune sand		SP				100		PID not functioning properly
50									
55									
60									
	dark yellowish brown (10YR 4/4), trace silt								
65	dark yellowish brown (10YR 4/6), medium-grained with some fine grained								
	fine to medium-grained								

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VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4
Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Type	Percent Recovery	REMARKS
70	sand, dark yellowish brown (10YR 4/6), fine to medium-grained, poorly graded, subrounded to subangular, slightly moist, trace silt, dune sand.	SP	100	PID not functioning properly.
	dark yellowish brown (10YR 4/4).			
75	dark yellowish brown (10YR 4/6).			
80	trace silt, trace clay.			
85	moist.			
	silty clay, very dark gray (10YR 3/1), very soft, trace fine-grained oxidized sand, alluvium.	CL		
	sand, brown (10YR 4/3), fine to medium-grained, subrounded to subangular, poorly graded, wet, alluvium.	SP		Bentonite transitional seal from 87 to 93 feet bgs.
90	dark yellowish brown (10YR 4/4), slightly moist.	⊽		

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4
Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
95	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, subrounded to subangular, poorly graded, slightly moist, alluvium.		SP				100		PID not functioning properly. Upper screened interval: 97 ft to 117 ft bgs. Groundwater encountered at 97.5 ft bgs during drilling.
100	wet.								
105									
110									
115	peat, dark brown (7.5 YR 3/3), soft, highly organic, few pine needles and gastropod fragments, some silt.		PT						
	sandy silt, organic, black (7.5YR 2.5/1), fine-grained, few gastropod and plant fragments, few clay, alluvium.		OL						14-INJ-3 2" PVC sump from 117 ft to 122 ft bgs. Bentonite transitional seal from 117 to 123 feet bgs.

R:\Boring Logs\MWells\14-INJ-3/14-INJ-4 p 5 of 7 11/20/03

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4213 State Street, Suite 100
Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4

Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
120	clay, bluish black (2.5 GLEY2 10B), stiff to very stiff, organic odor, trace angular gravel (siltstone and chert), trace fine-grained sand, alluvium		CL				100		PID not functioning properly. Bottom of 14-INJ-3 sump.
	silty clay, organic, bluish black (2.5 GLEY2 10B), very soft, organic odor, some silt, trace angular gravel (siltstone and chert), trace fine-grained sand, alluvium		OL						
125	silty sand, black (7.5YR 2.5/1), fine to medium-grained, poorly graded, subrounded, some silt, few angular gravel (siltstone), trace clay, alluvium.		SM						Lower screened interval: 125 ft to 150 ft bgs.
	few subrounded to subangular gravel (siltstone).								
130	fine-grained.								
135	little angular gravel (Monterey Shale).								
140	very dark gray black (10YR 3/1), fine-grained, poorly graded, subrounded to subangular, wet, trace clay,								
	little angular gravel (Monterey Shale).								

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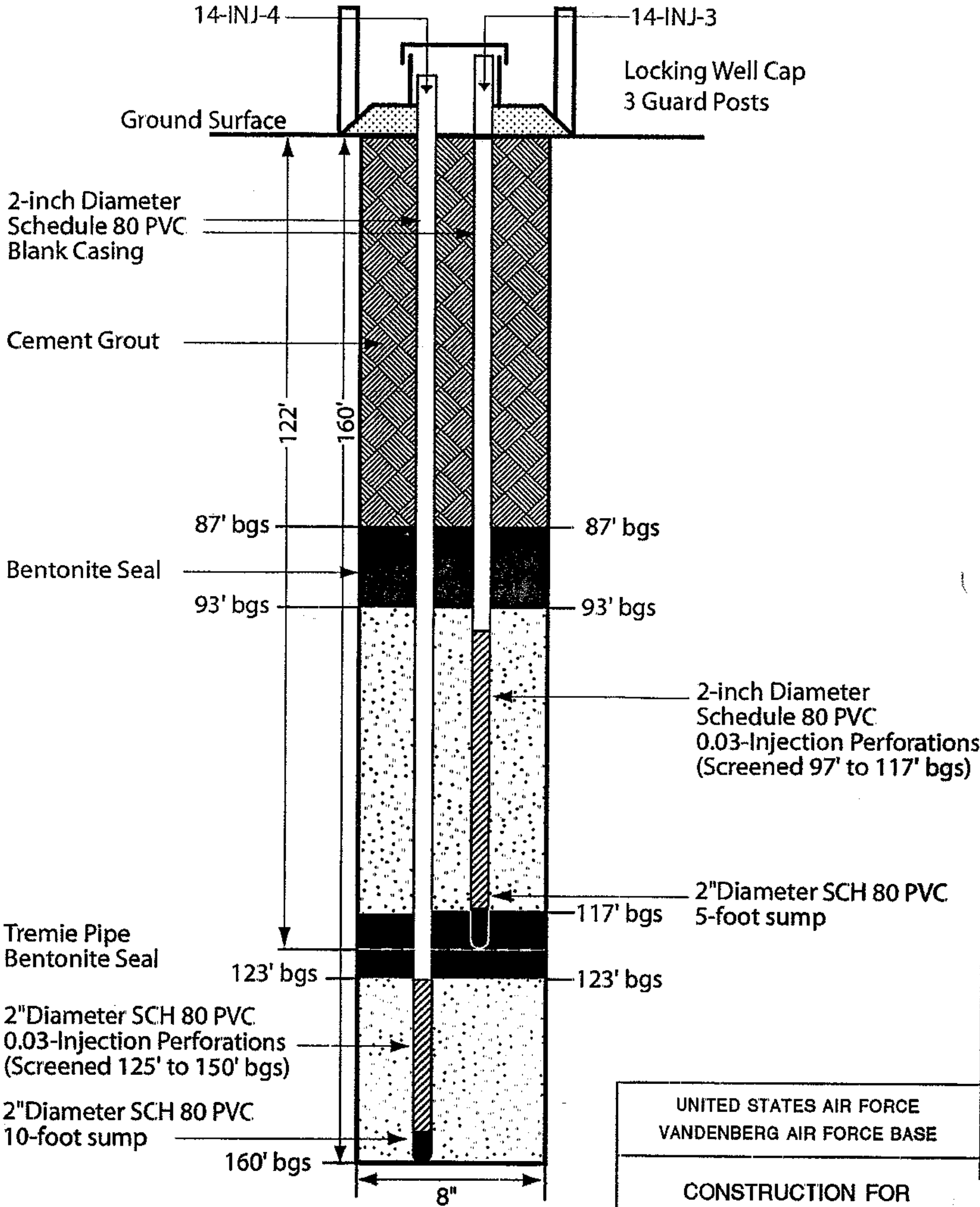
Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-3 / 14-INJ-4
Location: OU4, Site 14, approximately 895 feet southwest of Bldg. 1794, west of Watt Rd.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
145	clayey sand, dark greenish gray (5 GLEY 3/1), fine-grained, dense, few angular gravel (siltstone), slightly moist, alluvium		SC				100		PID not functioning properly
	silty sand, grayish brown (10YR 5/2), fine-grained, poorly graded, subrounded to subangular, slightly moist, little angular gravel (Monterey Shale), few silt. weathered Monterey Shale		SM						
150	shale, olive gray (5Y 5/2), weathered, wet, Monterey Shale.		SHALE						14-INJ-4 2" PVC sump from 150 ft to 160 ft bgs. 10-foot Sump.
155									
160									Total depth: 160 ft bgs.
165									

R:\Boring Logs\MWells\14-INJ-3/14-INJ-4 p 7 of 7 11/20/03

2-inch Diameter SCH 80 PVC Injection Wells



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

CONSTRUCTION FOR
INJECTION WELLS
14-INJ-3/4

TASK NO.	DATE	DRAWN BY	AI FILE NO.	FIGURE NO.
A250-48	9/10/03	RANDALL	G:\Irp-Restoration\ Irp-RI\Site13c Treatibility\ ProDesign 14-inj-3-4.ai	14-INJ-3/4

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VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg. 1794, west of Watt Road.

Date Started: 8/1/03	Completed: 8/5/03
Logged By: S. Serratore	Checked By: D. Springer, R. G. ZH RG # 6962
Drilled By: Ramon Zereda, BC2 Environmental Corp.	
Drilling Equipment: CME 95, 10" Hollow Stem Auger	
Sampling Equipment: 2" I.D. split spoon	
GS Elev.: 130 ft above MSL	ID: 131 ft

	Well		From		To	
2" PVC Bank Casing:	14-INJ-5:	from	0	ft bgs to	95	ft bgs
	14-INJ-6:	from	0	ft bgs to	121	ft bgs
2" Screened Casing:	14-INJ-5:	from	97	ft bgs to	111	ft bgs
	14-INJ-6:	from	121	ft bgs to	131	ft bgs
Bentonite/Cement Grout:	14-INJ-5:	from	0	ft bgs to	86	ft bgs
	14-INJ-6:	from	0	ft bgs to	86	ft bgs
Bentonite Transitional Seal:	14-INJ-5:	from	86	ft bgs to	91	ft bgs
	14-INJ-6:	from	116	ft bgs to	121	ft bgs
Sand Filter Pack:	14-INJ-5:	from	91	ft bgs to	116	ft bgs
	14-INJ-6:	from	121	ft bgs to	131	ft bgs

TOC Elev.: 132.68 ft above MSL

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
0	sand, dark yellowish brown (10YR 3/6), fine to medium-grained, poorly graded, subrounded, loose, dry, dune sand		SP						1115 Begin drilling 8/1/03. Lithology based on drilling cuttings and drill rate.
5									
10	yellowish brown (10YR 5/6), slightly moist, little silt.							0.3/ 0.1	
15									
20									

90 ft. bgs. Groundwater depth during drilling. 103.00ft. bgs Groundwater depth after well development on: 11/5/03

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Type	PID (ppm) Amb/Smp	REMARKS
20	sand, yellowish brown (10YR 5/6), fine to medium-grained, poorly graded, subrounded, loose, slightly moist, little silt, dune sand	SP		
25				
30	dense		0.1/ 0.1	
35				
40	dark yellowish brown (10YR 4/4)		0.2/ 0.1	

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Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg. 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
45	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, poorly graded, subrounded, dense, slightly moist, some silt, dune sand		SP						
50	moist							0.3/ 0.2	
55									
60								0.3/ 0.3	
65									Stop drilling. Resume drilling on Monday 8/11/03.

R:\Boring Logs\MWells\14-INJ-5/14-INJ-6 p 3 of 6 11/20/03

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VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Type	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
70	sand, dark yellowish brown (10YR 4/4), fine to medium-grained, poorly graded, subrounded, dense, moist, some silt, dune sand	SP	100		1030 Resume drilling on 8/4/03.
75					
80	dark yellowish brown (10YR 3/4), very moist.			0.2/ 0.2	
85	moist				
					Bentonite transitional seal from 86 to 91 feet bgs.
90	wet	▼			Groundwater encountered at 90 ft bgs during drilling.

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4213 State Street, Suite 100
Santa Barbara, CA 93110-2847
VOICE (805) 681-3100 FAX (805) 681-3108

Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg. 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
95	sand, dark yellowish brown (10YR 3/4), fine to medium-grained, poorly graded, subrounded, dense, wet, some silt, dune sand								14-INJ-5 Upper screened interval: 97 ft to 111 ft bgs
								0.2/ 0.1	Formation collapse around screen, no filter pack.
100	brown (10YR 4/3)								
105									
110									Bottom of 14-INJ-5 casing
115									
									Bentonite transitional seal from 116 to 121 feet bgs.

R:\Boring Logs\Wells\14-INJ-5/14-INJ-6 p 5 of 6 11/20/03

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4213 State Street, Suite 100
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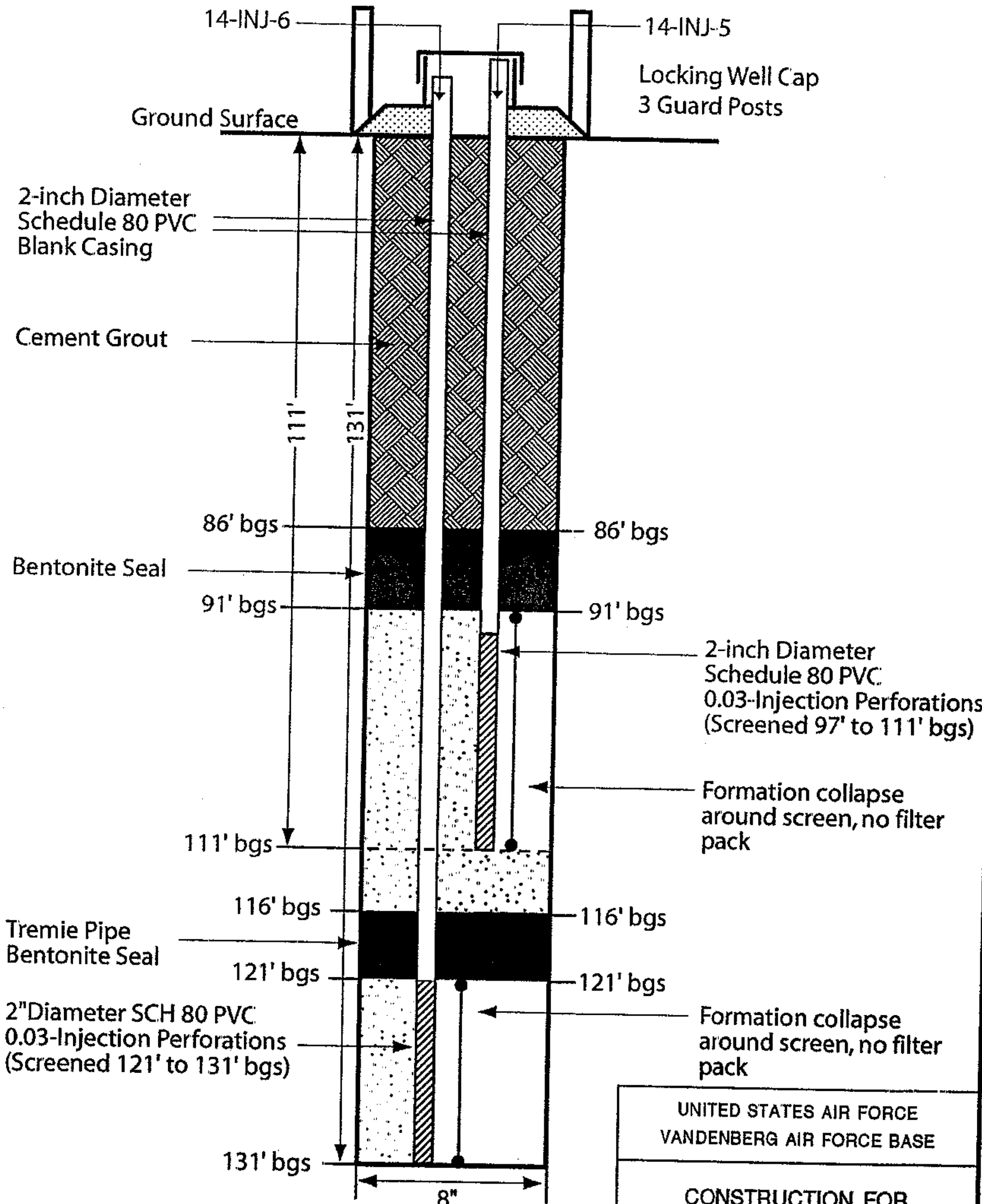
Project: Vandenberg Air Force Base/13C Treatiblity Study
Log of Well No. 14-INJ-5 / 14-INJ-6

Location: OU4, Site 14, approx. 895 feet southwest of Bldg. 1794, west of Watt Road.

Depth (ft. bgs)	MATERIAL DESCRIPTION	Material Symbol	Material Type	Well Construction	Sample	Blow Counts per 6"	Percent Recovery	PID (ppm) Amb/Smp	REMARKS
120	sand, brown (10YR 4/3), fine to medium-grained, poorly graded, subrounded, dense, wet, some silt, dune sand								Slow drill rate. Formation collapse around screen, no filter pack.
125									14-INJ-6 Lower screened interval: 121 ft to 131 ft bgs.
130	silty clay, organic, very dark grayish brown (10YR 3/2), dense, wet, some chert fragments, alluvium.		OH				0.2/ 0.0		Stop drilling. Resume on 8/5/03. Pull auger. Set we[ll] 14-INJ-6 on 8/5/03
135									
140									

2-inch Diameter SCH 80 PVC Injection Wells



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

CONSTRUCTION FOR
INJECTION WELLS
14-INJ-5/6

TASK NO.	DATE	DRAWN BY	AI FILE NO.	FIGURE NO.
A250-48	11/17/03	RANDALL	G:\Irp-Restoration\ Ifr-RI\Site13c Treatability\ ProDesign 14-inj-5-6.ai	14-INJ-5/6

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B SITE 13C APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Chemical-Specific ARARs						
Safe Drinking Water Act, 42 USC 300						
1	National Primary Drinking Water Standards	40 CFR, Part 141	Establishes maximum contaminant levels (MCLs) for public water systems	Relevant & Appropriate	The NCP defines MCLs as relevant and appropriate for groundwater determined to be a current or potential source of drinking water in cases where MCLGs are not ARARs. Groundwater in the vicinity of VAFB has been designated for potential drinking water use.	1, 2, 3, 4, 5
2	Maximum Contaminant Level Goals (MCLGs)	40 CFR, Part 141	Establishes potable water quality goals.	Relevant & Appropriate	MCLGs that have non-zero values are relevant and appropriate for groundwater to be a current or potential source of drinking water. Groundwater in the vicinity of VAFB has been designated for potential drinking water use.	1, 2, 3, 4, 5
Clean Water Act, 33 USC 1251 et seq.						
3	Water Quality Standards and Criteria	33 USC, 1313 and 57, Federal Register 60920-60921	Establishes the requirement of water quality standards for discharges to waters of the United States	Potentially Relevant & Appropriate	Applies to any potential site discharge to waters of the United States.	2, 3, 4, 5
Hazardous Waste Control Act (HWCA)						
4	Concentration limits of regulated units effluent to groundwater, surface water, and soil	Title 22, CCR, Div 4.5, Ch 14, §66264.94	Groundwater and vadose zone protection standards: RCRA hazardous waste TSD facilities shall comply and ensure that hazardous constituents entering the groundwater, surface water, and soil from a regulated unit do not exceed the concentration limit from contaminants of concern in the uppermost aquifer underlying the waste management area beyond the point of compliance.	Potentially Relevant & Appropriate	Applicable for hazardous waste TSD facilities; potentially relevant and in site-specific circumstances, such as when the source of waste is unknown but the waste is similar in composition to listed waste or when waste constituents have released or have the potential to release to groundwater. This site is not a TSD facility, and existing concentrations of constituents present in site mdeia are generally below levels that would classify them as hazardous waste.	2, 3, 4, 5
5	Hazardous waste listing and identification	Title 22, CCR, Div 4.5, Ch 11, §66261.2, §66261.3	Identification of hazardous waste that poses a potential hazard to human health or the environment when it is improperly treated, stored, transported, or disposed.	Potentially Relevant & Appropriate	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made at the time that wastes are generated.	2, 3, 4, 5
Resource Conservation and Recovery Act (RCRA)						
6	RCRA Hazardous Waste and toxic characteristics leaching procedure (TCLP) levels	Title 22, CCR	Defines RCRA hazardous waste and TCLP regulatory levels.	Potentially Relevant & Appropriate	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made at the time that wastes are generated.	2, 3, 4, 5
Cal/EPA DTSC						
7	Non RCRA Hazardous Waste; persistent and bioaccumulative toxic substances, total threshold limit concentrations (TTLCs), and soluble threshold limit concentrations (STLCs).	Title 22, CCR, Div 4.5, Ch. 11	Defines non-RCRA hazardous waste, persistent and bioaccumulative toxic substances, and regulatory levels for TTLC and STLC analyses.	Applicable	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made the time that wastes are generated.	2, 3, 4, 5
8	State maximum contaminant level (MCL) list	Title 22, CCR, Div 4, Ch. 15	The primary MCLs are drinking water quality standards established by the U.S. EPA under the Safe Drinking Water Act, the State of California under Domestic Water Quality and Monitoring Regulations. Primary MCLs present risk to the human health when used for drinking or culinary purposes.	Relevant & Appropriate	State MCLs are tap water standards that are relevant and appropriate for the potential drinking water aquifers at VAFB.	2, 3, 4, 5
9	State Secondary MCL list	Title 22, CCR, Div 4, Ch15	Secondary MCLs may be objectionable to an appreciable number of people but are not generally hazardous to human health.	Potentially Relevant & Appropriate	None of the chemicals of concern for the Site 13C EE/CA have secondary MCLs.	1, 2, 3, 4, 5
State and Regional Water Quality Control Board (RWQCB)						
10	Porter Cologne Water Quality Control Act (California Water Code Sections 13240, 13241, 13242, 13243)	Water Quality Control Plan (Basin Plan) for the RWQCB, CCR includes the State Water Resources Control Board's Water Quality Control Plan for Ocean Waters of California (Ocean Plan)	Establishes water quality objectives, including narrative and numerical standards, that protect the beneficial uses and water quality objectives of surface and ground waters in the region. Describes implementation plans and other control measures designed to ensure compliance with statewide plans and policies and provide comprehensive water quality planning.	Applicable	Specific applicable portions of the Basin Plan include beneficial uses of affected water bodies and water quality objectives to protect those uses. Any activity, including, but not limited to, the discharge of contaminated soils or waters or in-situ treatment or containment of contaminated soils or waters, must not result in actual water quality exceeding water quality objectives. The Basin Plan for RWQCB CCR assigns the beneficial use of drinking water to all groundwater in the region (with the exception of the Soda Lake sub-basin). The Basin Plan supercedes Resolution 88-63, therefore, the beneficial use of drinking water must be protected regardless of the Resolution's criteria.	2, 3, 4, 5
11	Porter Cologne Water Quality Control Act (California Water Code Sections 13000, 13140, 13240)	State Water Resources Control Board Resolution (SWRCB) 88-63 (Source of Drinking Water Policy)	Designates all ground and surface waters of the State as drinking water except where the TDS is greater than 3,000 ppm, the well yield is less than 200 gpd from a single well, the water is a geothermal resource or in a water conveyance facility, or the water cannot reasonably be treated for domestic purposes using either best management practices or best economically achievable treatment practices.	Applicable	Applies in determining beneficial uses for waters that may be affected by discharges of waste. The groundwater at VAFB has been identified as a source of drinking water.	1, 2, 3, 4, 5

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Chemical-Specific ARARs						
State and Regional Water Quality Control Board (RWQCB)						
12	Policy Regarding Maintenance of Water Quality in California	SWRCB Resolution 68-16 (Policy with Respect to Maintaining High Quality Waters in California)	Requires that quality of waters of the State is better than needed to protect all beneficial uses be maintained unless certain findings are made. Discharges to high quality waters must be treated using best practicable treatment or controls necessary to prevent pollution or nuisance and to maintain the highest quality water. Requires cleanup to background water quality or to lowest concentrations technically and economically feasible to achieve Beneficial uses must, at least, be protected.	Applicable	Applicable for any surface discharge or subsurface injection of treated water.	3, 4, 5
13	Porter-Cologne Water Quality Control Act	Water Code, Div. 7, §13000 et seq.	Establishes authority of State and Regional Water Boards to protect water quality by regulating waste disposal and requiring cleanup of hazardous conditions that affect waters of the state. Defines designated waste; sets requirements for laboratories; sets report requirements for waste discharges and specifies well drilling requirements and reporting.	Applicable	Defines waste and sets requirements for investigations and analyses.	2, 3, 4, 5
14	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20400, Title 23, CCR, §2550.4.	Concentration limits must be established for groundwater, surface water, and the unsaturated zone. Must be based on background, equal to background, or for corrective actions, may be greater than background, not to exceed the lower of the applicable water quality objective or the concentration technologically or economically achievable. Specific factors must be considered in setting cleanup standards above background levels.	Applicable	Applies in setting ground water cleanup levels for any discharges of waste to land.	3, 4, 5
15	California Safe Drinking Water Act (California Health & Safety Code Section 4010 et seq.)	Title 22, CCR, §64400 et seq.	Requirements for public water systems. Includes MCLs and Secondary MCLs.	Relevant & Appropriate	The act is legally applicable for an aquifer and associated distribution and pre-treatment system that is currently defined as "public water system" If it is only a potential "Public water system," then the act is relevant and appropriate.	N/A
16	Safe Drinking Water & Toxic Enforcement Act (aka Prop. 65)	Health and Safety Code, Division 20, Chapt. 6.6, §25249.5 et seq.	Prohibits discharges of specified carcinogens and reproductive toxins into current or potential drinking water sources.	Relevant & Appropriate	Prohibits discharges of specific substances to drinking water sources.	2, 3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities*
DTSC Human and Ecological Risk Division

2 *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities*
DTSC Human and Ecological Risk Division

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Location-Specific ARARs						
17	National Archaeological and Historical Preservation Act	16 USC, 469a-1 and 36 CFR 65	Construction on previously undisturbed land would require an archaeological survey of the area	Applicable	Archaeological surveys have been conducted at VAFB: archaeological monitors should to be present to clear all drilling locations in order to protect cultural resources.	3, 4, 5
18	Endangered Species Act of 1973	16 USC, 1536(a)	Action to protect critical habitat upon which endangered species or threatened species depend must be taken.	Applicable	Sensitive habitat mitigation measures will be followed during implementation of this IRA including the migration patterns of the Snowy Plover.	3, 4, 5
19	Fish and Game Code	Fish and Game Code, §2080	No person shall import, export, take, possess, or sell any endangered or threatened species or part of product thereof.	Potentially Applicable	Endangered species are present at VAFB such as the California Red-legged Frog and the Snowy Plover.	1, 2, 3, 4, 5
20	Within 200 feet of a fault displacement in Holocene time	Title 22, CCR, Div 4.5, Ch 14, §66264.18	New facility for treatment, storage, or disposal of hazardous waste prohibited.	Potentially Relevant & Appropriate	The location requirements are considered relevant and appropriate for the siting of remedial systems to reduce the toxicity, volume and/or mobility of chemicals.	5
21	Within a 100-year floodplain	Title 22, CCR, Div 4.5, Ch 14, §66264.18	Facility must be designed, constructed, operated, and maintained to prevent washout by flood or maximum high tide.	Potentially Relevant & Appropriate	Same as above	5
22	Porter-Cologne Water Quality Control Act (California Water Code Section 13000 et seq.)	California Water Code, §13243	The RWQCB may specify certain conditions or areas where the discharge of waste, or certain types of waste, will not be permitted.	Applicable	Applies to groundwater remedial action.	3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Drilling, Coring, Sampling and Logging at Hazardous Substance Release sites*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

2 *Reporting Hydrogeologic Characterization Data at Hazardous Substance Release sites*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

3 *Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites, Volume 1 & 2*
Cal/EPA, July 1995

4 *Aquifer Testing for Hydrogeologic Characterization*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

5 *Application of Borehole Geophysics at Hazardous Substance Release Sites*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

6 *Ground Water Modeling for Hydrogeologic Characterization*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

7 *Monitoring Well Design and Construction for Hydrogeologic Characterization*
Guidance Manual for Ground Water investigations
Cal/EPA, July 1995

8 *Advisory – Active Soil Gas Investigation*
DTSC/CRWQCB-Los Angeles Region, January 2003

9 *Representative Sampling of Ground Water for Hazardous Substances*
Cal/EPA, July 1995

10 *Accumulating Hazardous Waste at Generator Sites*
Cal/EPA, July 1995

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
23	Offsite Management Requirements for CERCLA Wastes	58 CFR 49200-49218 40 CFR 300.440	Establishes requirements for managing CERCLA response action wastes at offsite Treatment, Storage and Disposal (TSD) facilities.	Applicable	Applicable for off-site treatment or disposal of removed materials (e.g., drill cuttings, construction materials, or purge waters).	2, 3, 4, 5
24	National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122-125	Requires permits for the discharge of pollutants from any point source into the waters of the United States.	Relevant & Appropriate	Best management practices will be implemented to protect storm water discharges.	5
25	Hazardous Waste Control Act (HWCA)	Title 22, CCR, Div 4.5, §66262.10(a), §66262.11	Requires that the generator shall determine if a waste is hazardous waste.	Applicable	Applicable for any operation where waste is generated.	2, 3, 4, 5
26	HWCA	Title 22, CCR, Div, 4.5, §66262.34	Generator may accumulate waste on site for 90 days or less or must comply with requirements for operating a storage facility	Applicable	No storage of hazardous waste is planned as part of this IRA. Accumulation of hazardous wastes on site for longer that 90 days would be subject to RCRA requirements for storage facilities.	2, 3, 4, 5
27	HWCA	Title 22, CCR, Div 4.5, §66262.40, §66262.41	Generator must keep records of manifests, test results and waste analyses.	Applicable	Applicability of this requirement is contingent upon generation and management of hazardous waste.	2, 3, 4, 5
28	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.12	A generator shall not treat, store, dispose of, transport or offer for transportation, hazardous waste without having received an identification number.	Applicable	Applicable for any operation where waste is generated. The determination of whether wastes generated during remedial activities are hazardous shall be made when the wastes are generated.	2, 3, 4, 5
29	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.20, §66262.22	A generator of hazardous waste who transports or offers hazardous waste for transportation shall prepare a manifest.	Applicable	Same as above.	2, 3, 4, 5
30	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.30, §66262.31, §66262.32, and §66262.33	Before transporting hazardous waste or offering hazardous waste for transportation off-site, the generator must do the following in accordance with DOT regulations: package the waste, label and mark each package of hazardous waste, and ensure that the transport vehicle is correctly placarded.	Applicable	Same as above.	2, 3, 4, 5
31	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 2	Establish requirements for a hazardous waste treatment facility to have a plan for waste analysis, develop a security system, conduct regular inspections, provide training to facility personnel, and use a quality assurance program during construction.	Potentially Relevant & Appropriate	Site 13 Cluster is not a TSD facility. The determination of whether wastes generated during remedial activities are hazardous shall be made when the wastes are generated.	2, 3, 4, 5
32	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 3, 4	Establish requirements for a facility to plan for emergency conditions. In addition, the design and operation of the facility must be done to prevent releases. Other requirements include testing and maintenance of equipment and incorporation of communication and alarm systems and contingency plan.	Potentially Relevant & Appropriate	Same as above.	2, 3, 4, 5
33	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 9	The remedial activities may involve treatment within containers and/or storage of treatment residuals in containers. These containers must be in good condition, compatible with the waste, kept closed except to add or remove materials and be inspected weekly. The area used to store the containers must provide adequate secondary containment and be designed with runoff controls. Also, appropriate closure of the containers must take place.	Potentially Relevant & Appropriate	The requirements may be applicable if CERCLA response action constitutes treatment, storage, or disposal as defined under RCRA, or may be relevant and appropriate if the requirements address problems or situations sufficiently similar to the specific circumstances at the site that their usage will be well suited. Site 13 Cluster is not a TSD facility.	2, 3, 4, 5
34	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 10	The remedial activities may involve storage and/or treatment in tanks. These tanks are required to have secondary containment, be monitored and inspected, be provided with overfill and spill protection controls, and operated with adequate freeboard. Also, appropriate closure must take place.	Potentially Relevant & Appropriate	Same as above.	2, 3, 4, 5
35	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 12	The waste piles should be placed upon a lined foundation or base with a leachate system, protected from precipitation and wind dispersal, designed to prevent run on and run off. Also, closure and post-closure care requirements.	Potentially Relevant & Appropriate	Remedial action may involve soil excavation and the compiling of soil in a temporary waste pile for the injection barrier.	3, 4, 5
36	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 16	Applies to waste management unit not otherwise regulated under RCRA. It may include pumps, auxiliary equipment, air strippers, etc. The substantive requirements include design, construction, operation, maintenance and closure of the unit that will ensure protection of human health and the environment. The actions include general inspections for safety and operation efficiency, testing and maintenance of the equipment (including testing of warning systems).	Potentially Relevant & Appropriate	Remedial activities may involve the use of pumps, auxiliary equipment, air strippers, piping, etc. for Site 13 In-Situ Bioremediation, In-Situ Oxidation, and Ex-Situ Groundwater treatment. Double wall piping and leak detection will be required if the waste meets the RCRA hazardous waste criteria.	3, 4, 5

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
37	HWCA	Title 22, CCR, Div 4.5, Ch 18, Article 1, 3, 4, 10, 11	Movement of hazardous waste to new locations and placed in or on land will trigger LDR. General applicability, dilution prohibited, waste analysis and record keeping, and special rules apply for wastes that exhibit a characteristic waste. Best Demonstrated Available Technology (BDA) standards for each hazardous constituents in each listed waste, if residual is to be disposed. Treatment standards table when necessary.	Applicable	Where applicable, hazardous waste generated from remedial activities must comply with LDR and meet or notify the disposal facility of the treatment standards before disposal at an appropriate offsite disposal facility.	2, 3, 4, 5
38	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.111, §66264.112, §66264.115 through 120	Owners and operators shall close a facility and perform post-closure care when contaminated subsurface soil cannot be practically removed or decontaminated.	Relevant and Appropriate	Contaminated soil, residues, or groundwater from remedial action at a site will achieve clean closure, otherwise, post-closure care requirements will be relevant and appropriate.	3, 4, 5
39	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.91 (a) and (c)	Owners or operators of a RCRA surface impoundment, waste pile, land treatment unit, or landfill shall conduct a monitoring and response program for each regulated unit.	Potentially Relevant & Appropriate	Substantive technical requirements are potentially relevant and appropriate for remedial action including groundwater monitoring.	2, 3, 4, 5
40	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.97 (b), (c), (d) and (e)(1) through (e)(5)	Requirements for monitoring groundwater, surface water, and vadose zone.	Potentially Relevant & Appropriate	Same as above	2, 3, 4, 5
41	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.193 (b) and (c)	In order to prevent release of hazardous constituents to the environment, tank systems, including ancillary equipment, shall have secondary containment (e.g., double-wall piping).	Potentially Relevant & Appropriate	Applicable to conventional remedial systems.	3, 4, 5
42	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.98	Requires the owner or operator of a regulated unit to develop a detection monitoring program that will provide reliable indication of a release.	Potentially Relevant & Appropriate	Same as above	3, 4, 5
43	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.99	Requires the owner or operator of a regulated unit to develop an evaluation monitoring program that can be used to assess the nature and extent of a release from the unit.	Potentially Relevant & Appropriate	Same as above	3, 4, 5
44	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.100 (a) through (d), (f), (g)(1), and (h)	The owner or operator is required to take corrective action under Title 22, CCR, §66264.91 to remediate releases from the regulated unit and to ensure that the regulated unit achieves compliance with the water quality protection standard.	Relevant and Appropriate	Same as above	3, 4, 5
45	Safe Water Drinking Act (SFDA), Underground Injection Control (UIC) Regulations Toxic Injection Well Control Act of 1985	40 CFR, §260.10 Parts 144 through 147 Cal. Health and Safety Code, §25159.10 through 25	Establishes minimum requirements for UIC programs such as permits for the injection wells. Injection may not cause a violation of the primary MCLs and requires the evaluation of the quality of water.	Applicable	Potentially applicable for alternative utilizing a groundwater injection option to aquifers that are or may reasonable be expected to be a source of drinking water. If the treated water is most likely to be at or below the applicable primary MCLs, it is highly unlikely to be classified as either a RCRA or non-RCRA hazardous waste. Consequently, the reinjection wells would be Class V wells under SDWA UIC regulations. The substantive requirements of UIC regulations for Class V wells need to be met.	3, 4, 5
46	California Health and Safety Code California Civil Code	Cal. Health and Safety Code, §25202.5, 25222.1 Cal. Civil Code, §1471	Allows DTSC to enter into an agreement with the owner of a hazardous waste facility to restrict present and future land usages. Provides a streamlined process to be used for entering into an agreement to restrict specific usage of property in order to implement land-use restrictions	Relevant and Appropriate	The substantive provisions of Cal. Health and Safety Code (HSC), §25202.5 are the general narrative standards to restrict "[p]resent and future uses of all or part of the land on which the … facility … is located …" HSC §25222.1 provides the authority for the state to enter into voluntary agreement to establish land-use covenants with the owner of the property. The substantive provision of this section is the general narrative standard "[restricting specified uses of the property]". Cal. Civil Code §1471 provides conditions under which land-use restrictions will apply to successive owners of land.	1, 2, 3, 4, 5
47	Occupational Health and Safety Act	Cal. Health and Safety Code, Div 5, §6300 et seq.	Specific requirements that employers must meet to ensure the safety of the employees	Relevant and Appropriate	The provisions of this act should be followed for the removal action. A health and safety plan has been developed for the proposed removal action and is contained in the IRA Work Plan.	2, 3, 4, 5

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
48	CCR	Title 22, CCR, §66264	Container storage requirements and storage time limitations	Applicable	Applicability of this requirement is contingent upon generation and management of hazardous waste.	2, 3, 4, 5
49	U.S. Department of Transportation	49 CFR, 171-172	Regulates storage, packaging, labeling, and placarding requirements for hazardous materials with regards to transportation.	Applicable	Portions of these requirements would be ARARs for transport of material on site. Off-site transport must comply with both substantive and administrative requirements.	2, 3, 4, 5
50	State Hazardous Waste Regulations Discharges of Waste to Land	Title 23, CCR, §2510-§2600	Regulates waste discharges to land that may affect water quality. Includes siting, design, construction, operation, closure and monitoring standards and criteria for establishing cleanup levels.	Applicable	Substantive requirements of these regulations are applicable at Site 13C.	2, 3, 4, 5
51	Hazardous Waste Control Act as implemented by Standards for Generators of Hazardous Waste	Health and Safety Code, Sec. 25100 et seq., Title 26, CCR, Div. 22, §66262	Establishes state hazardous program in lieu of federal RCRA. Establishes standards for generators and transporters of hazardous wastes in California. Authorization for state program was obtained from U.S. EPA in 1992. Establishes recordkeeping, reporting and manifesting standards for hazardous waste generators in California. Establishes storage accumulation time, requires hazardous waste determination, specifies labeling, container segregation of incompatible wastes, and secondary containment requirement.	Applicable	CERCLA sites are exempt from these administrative requirements. Substantive requirements will apply for any offsite transportation of wastes from Site 13C.	2, 3, 4, 5
52	Hazardous Waste Control Act as implemented by Land Disposal Restrictions	Title 22, CCR, Div. 4.5, §66268	Identifies wastes and chemical concentration levels that are restricted from land disposal.	Applicable	Will be applicable for drill cuttings or treatment residuals with chemical concentrations exceeding regulatory levels.	3, 4, 5
53	Hazardous Waste Control Act as implemented by Corrective Action Management Units (CAMU)	Title 22, CCR, Div. 4.5, §66264.552	Establishes location and operating requirements for Corrective Action Management Units used in remedial actions.	Applicable	Applicable for treatment units for excavated soil (e.g., drill cuttings), landfilled material, or extracted water. Applies to both RCRA and non-RCRA wastes.	5
54	Hazardous Waste Control Act as implemented by Temporary Units	Title 22, CCR, Div. 4.5, §66264.553	Allows Department of Toxic Substances Control (DTSC) to approve design, operation and closure standards for temporary units used for treatment or storage of wastes generated during remedial actions. DTSC may require alternative standards more protective of human health and the environment.	Relevant & Appropriate	Relevant and appropriate for remedial alternatives that include the use of temporary on-site treatment units.	5
55	Hazardous Waste Control Act as implemented by Miscellaneous Units	Title 22, CCR, Div. 4.5, §66264.600-§66264.603	Establishes standards for environmental performance, monitoring, inspections and post-closure care for miscellaneous units used in waste treatment, storage, or disposal.	Applicable	Substantive portions will be applicable for remedial alternatives.	5
56	Water Well Standards	Dept. of Water Resources Bulletin 74-81 and 74-90	Sets requirements for the construction and abandonment of water extraction and injection wells throughout the state.	Applicable	Will apply for any monitoring, injection, or extraction wells constructed or abandoned during remedial actions.	2, 3, 4, 5
57	Waste Discharge Requirements	Water Code Sec. 13260 et seq. (Porter-Cologne Water Quality Control Act)	Requires filing of a "Report of Waste Discharge" with the RWQCB for any proposed discharges affecting "the waters of the state."	Potentially Applicable	Under CERCLA, on-site actions are exempt from reporting requirements. However, the reporting requirement must be met for any offsite discharges.	N/A
58	Policies and Procedures for Investigation and Cleanup and Abatement and Closure	California Water Code 13304 as implemented by State Water Resources Control Board Resolution No. 92-49	Establishes policies and procedures for oversight of investigations, cleanups and abatement activities resulting from discharges which affect or threaten water quality.	Applicable	Applicable for all cleanup and abatement activities which may cause or permit discharges to waters of the state and create or threaten to create a condition of pollution or nuisance in violation of any waste discharge requirement.	5
59	Hazardous Materials Release Response Plans and Inventory	Health and Safety Code, Div. 20, Chapter 6.95	Establishes requirements for emergency response plans for a release or threatened release of hazardous materials. Reporting requirements are established.	Applicable	Substantiative requirements will be applicable to sites with remedial actions where hazardous materials may be handled.	3, 4, 5
60	Staff Report of the RWQCB, CVR	"A Compilation of Water Quality Goals"	Provides guidance on selecting numerical values to implement narrative water quality objectives contained in the Basin Plan.	To Be Considered	Performance Standard. To be considered in selecting appropriate numerical values to implement the Basin Plan for setting cleanup levels and discharge limits. The numerical values contained in the staff report may be ARAR's, or Performance Standards, depending on the source of the values.	3, 4, 5

Table B-1
ARARs for Site 13 Cluster
Groundwater IRA

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
61	Porter-Cologne Water Quality Control Act (California Water Code Sections13000, 13140, 13240, 13260, 13263, 13267, 13300, 13304, 13307)	State Water Resources Control Board Resolution No. 92-49 (As amended April 21, 1994)	Establishes requirements for investigation and cleanup and abatement of discharges. Among other requirements, dischargers must clean up and abate the effects of discharges in a manner that promotes the attainment of either background water quality, or the best water quality that is reasonable if background water quality cannot be restored. Requires the application of Title 23, CCR, Section 2550.4, requirements to cleanups.	Applicable	Applies to groundwater remedial actions.	3, 4, 5
62	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20090(d), Title 23, CCR, §2511 (d)	Action taken by public agencies to clean up unauthorized releases are exempt from Title 27/ Title 23 accept that wastes removed from immediate place of release and discharged to land must be managed in accordance with classification (Title 27, CCR, Section 20200/ Title 23, CCR, Section 2520) and siting requirements of Title 27 or Title 23 and wastes contained or left in place must comply with Title 27 or Title 23 to the extent feasible.	Applicable	Applies to remediation and monitoring of sites.	2, 3, 4, 5
63	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20410, Title 23, CCR, §2550.6	Requires monitoring for compliance with remedial action objectives for three years from the date of achieving cleanup standards.	Applicable	Applies to groundwater remedial actions.	3, 4, 5
64	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20415, Title 23, CCR, §2550.7.	Requires general soil, surface water, and ground water monitoring.	Applicable	Applies to all areas at which waste has been discharged to land.	2, 3, 4, 5
65	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title, 27, CCR, §20425, Title, 23, CCR, §2550.9.	Requires an assessment of the nature and extent of the release, including a determination of the spatial distribution and concentration of each constituent.	Applicable	Applies to areas at which monitoring results show statistically significant evidence of a release.	2, 3, 4, 5
66	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20430, Title 23, CCR §2550.10	Requires implementation of corrective action measures that ensure that cleanup levels are achieved throughout the zone affected by the release by removing the waste constituents or treating them in place. Source control may be required. Also requires monitoring to determine the effectiveness of the corrective actions.	Applicable	Applies to groundwater remedial actions.	3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Institutional Control Protocol at Open Bases*
California Military Environmental Coordination Committee (CMECC)
Site Cleanup Performance Action Team

Table B-2

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS †
Vandenberg Air Force Base, California
(For soil ARARs, attenuate water criteria for metals by 100 and attenuate organics by 10)

CONSTITUENT	Water Criteria										Hazardous Waste Criteria		
	Maximum Contaminant Level[1]				CA Action Levels[2]		NAWQC[3] (EPA)			Prop. 65	EPA	CA	
	CA Primary	CA Secondary	EPA Primary	EPA Secondary	Toxicity	Taste/ Odor	Non-Cancer Public Health Effects	Cancer Risk Per Million	Aquatic Organisms Consumption[4]	MCL CA[5]	TCLP[6] (mg/L)	STLC[7] (mg/L)	TTLC[7] (mg/kg)
Inorganic Metals													
Aluminum	1,000	200		50 to 200									
Antimony	6		6				14		4,300			15	500
Arsenic	50		10					0.018 (m)	0.14	5	5	5	500
Barium	1,000		2,000				1,000				100	100	10,000
Beryllium	4		4							(j)		0.75	75
Cadmium	5		5							(j)	1	1	100
Chromium (VI)										(j)		5	500
Chromium (total)	50		100								5	560	2,500
Cobalt												80	8,000
Copper		1,000	1,300 (f)	1,000								25	2,500
Iron		300		300									
Lead			15 (f)							0.25 (k)	5	5	1,000
Manganese		50		50									
Mercury (inorganic)	2		2				0.14 (m)		0.15		0.2	0.2	20
Molybdenum												350	3,500
Nickel	100		100				610 (m)		4,600	(j)		20	2,000
Selenium	50		50									20	2,000
Silver		100		100							1	[illegible]	100
Thallium	2		2				1.7		6.3		5	5	500
Vanadium					15							7	700
Zinc		5,000										24	2,400
												250	5,000
Common Anions													
Chloride		250,000 (e)		250,000			250,000						
Cyanide	200		200				700		220,000				
Fluoride	1,400 to 2,400 (a)		4,000	2,000								180	18,000
Nitrate	45,000 (b)		10,000 (c)				10,000 (n)						
Nitrite	1,000 (c)		1,000 (c)										
Perchlorate					18								
Sulfate		250,000 (e)	400,000-500,000 (g)	250,000									
Fuels													
Hydrazine										0.02			
NDMA (N-Nitrosodimethylamine)								0.00069	8.1	0.02			
TPH *													

Values are in ug/L (ppb) unless otherwise indicated. Letters in parentheses indicate footnotes on the last page.

Tab 2

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS †

Vandenberg Air Force Base, California

(For soil ARARs, attenuate water criteria for metals by 100 and attenuate organics by 10)

CONSTITUENT	Water Criteria										Hazardous Waste Criteria		
	Maximum Contaminant Level[1]				CA Action Levels[2]		NAWQC[3] (EPA)			Prop. 65	EPA	CA	
	CA Primary	CA Secondary	EPA Primary	EPA Secondary	Toxicity	Taste/ Odor	Non-Cancer Public Health Effects	Cancer Risk Per Million	Aquatic Organisms Consump-tion[4]	MCL CA[5]	TCLP[6] (mg/L)	STLC[7] (mg/L)	TTLC[7] (mg/kg)
Volatiles													
Benzene	1		5					1.2	71	3.5	0.5		
Bromodichloromethane	100 (d)		100 (d) / 80 (g)					0.27	22	2.5			
Bromoform	100 (d)		100 (d) / 80 (g)					4.3	360	45 (l)			
Bromomethane							48		4,000	500 (k,l)			
Carbon tetrachloride	0.5		5					0.25	4.4	2.5	0.5		
Chlorobenzene	70		100				680		21,000		100		
Chloroform (Trichloromethane)	100 (d)		100 (d) / 80 (g)					5.7	470	10	6		
Chloromethane													
Dibromochloromethane	100 (d)		100 (d) / 80 (g)					0.41	34	3.5			
1,2-Dibromoethane (EDB)	0.05		0.05										
1,4-Dichlorobenzene	5		75	5 (g)			400 (o)		2,600	10	7.5		
1,1-Dichloroethane	5									50			
1,2-Dichloroethane	0.5		5					0.38	99	5	0.5		
1,1-Dichloroethylene	6		7					0.057	3.2		0.7		
cis-1,2-Dichloroethylene	6		70										
trans-1,2-Dichloroethylene	10		100										
Methylene Chloride (Dichloromethane)	5		5					4.7	1,600	25			
Methyl t-butyl ether (MtBE)			13	5									
1,2-Dichloropropane	5		5										
cis-1,3-Dichloropropene	0.5						10		1,700	2 (l)			
trans-1,3-Dichloropropene	0.5						10		1,700	2 (l)			
Ethylbenzene	700		700	30 (g)			3,100		29,000				
Styrene	100		100	10 (g)									
1,1,2,2-Tetrachloroethane	1							0.17	11	1.5			
Tetrachloroethylene (PCE)	5		5					0.8	8.85	7	0.7		
Toluene	150		1,000	40 (g)			6,800		200,000	3,500 (k)			
1,1,1-Trichloroethane	200		200										
1,1,2-Trichloroethane	5		5					0.6	42	5			
Trichloroethylene (TCE)	5		5					2.7	81	25	0.5	204	2,040
Trichlorofluoromethane	150							0.19					
Vinyl chloride	0.5		2					2	525	1.5	0.2		
Xylene(s)	1,750		10,000	20 (g)									
Semivolatiles													
Acenaphthylene													

Values are in ug/L (ppb) unless otherwise indicated. Letters in [illegible]

Table B-2

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS †

Vandenberg Air Force Base, California

(For soil ARARs, attenuate water criteria for metals by 100 and attenuate organics by 10)

CONSTITUENT	Water Criteria: Maximum Contaminant Level[1] CA Primary	CA Secondary	EPA Primary	EPA Secondary	CA Action Levels[2] Toxicity	Taste/ Odor	NAWQC[3] (EPA) Non-Cancer Public Health Effects	Cancer Risk Per Million	Aquatic Organisms Consump-tion[4]	Prop. 65 MCL CA[5]	Hazardous Waste Criteria: EPA TCLP[6] (mg/L)	CA STLC[7] (mg/L)	CA TTLC[7] (mg/kg)
Bis(2-chloroethyl) ether								0.031	1.4	0.15			
Butyl benzyl phthalate			100 (g)										
1,2-Dichlorobenzene	600		600	10 (g)	130 (h)	10	2,700		17,000				
3,3'-Dichlorobenzidine								0.04	0.077	0.3			
2,4-Dichlorophenol							93		790				
Bis(2-ethylhexyl)phthalate (Di(2-ethylhexyl)phthalate)	4		6					1.8	5.9	40			
Diethyl phthalate							23,000		120,000				
2,4-Dimethylphenol						400							
Dimethyl phthalate							313,000		2,900,000				
2,4-Dinitrophenol							70		14,000				
2,4-Dinitrotoluene								0.11	9.1	1	0.13		
Hexachlorobenzene	1		1					0.00075	0.00077	0.2	0.13		
Hexachlorobutadiene								0.44	50		0.5		
Hexachlorocyclopentadiene	50		50	8 (g)			240		17,000				
Hexachloroethane								1.9	8.9	10	3		
Isophorone								8.4	600				
Nitrobenzene							17		1,900		2		
N-Nitrosodiphenylamine								5	16	40			
N-Nitrosodipropylamine										0.05			
Pentachlorophenol	1		1					0.28	8.2	20	100	1.7	17
Phenol						5.0 (i)	21,000		4,600,000				
1,2,4-Trichlorobenzene	70		70										
2,4,5-Trichlorophenol							2,600						
2,4,6-Trichlorophenol								2.1	6.5	5	2		
Polycyclic Aromatic Hydrocarbons													
Anthracene							9,600		110,000				
Benz(a)anthracene			0.1 (g)					0.0028 (q)	0.031	0.02 (l)			
Benzo(b)fluoranthene			0.2 (g)					0.0028 (q)	0.031	0.02 (l)			
Benzo(k)fluoranthene								0.0028 (q)	0.031				
Benzo(g,h,i)perylene													
Benzo(a)pyrene	0.2		0.2					0.0028 (q)	0.031	0.03			
Chrysene			0.2 (g)					0.0028 (q)	0.31	0.1 (l)			
Dibenz(a,h)anthracene								0.0028 (q)	0.031	0.1			
Fluoranthene							300		370				
Indeno(1,2,3-c,d)pyrene								0.0028 (q)	0.031				

Values are in ug/L (ppb) unless otherwise indicated.   Letters in parentheses indicate footnotes on the last page.

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APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS †
Vandenberg Air Force Base, California
(For soil ARARs, attenuate water criteria for metals by 100 and attenuate organics by 10)

CONSTITUENT	Water Criteria										Hazardous Waste Criteria		
	Maximum Contaminant Level[1]				CA Action Levels[2]		NAWQC[3] (EPA)			Prop. 65 MCL CA[5]	EPA	CA	
	CA Primary	CA Secondary	EPA Primary	EPA Secondary	Toxicity	Taste/ Odor	Non-Cancer Public Health Effects	Cancer Risk Per Million	Aquatic Organisms Consump-tion[4]		TCLP[6] (mg/L)	STLC[7] (mg/L)	TTLC[7] (mg/kg)
Phenanthrene													
Pyrene							960		11,000				
Pesticide/Herbicide/PCBs													
Aldrin					0.05 (t)			0.00013	0.00014	0.02		0.14	1.4
a-BHC					0.7			0.0039	0.013	0.15			
b-BHC					0.3			0.014	0.046	0.25			
g-BHC (Lindane)	0.2		0.2					0.019	0.063	0.3	0.4	0.4	4
Chlordane	0.1		2					0.00057	0.00059	0.25	0.03	0.25	2.5
Dieldrin					0.05 (t)			0.00014	0.00014	0.02		0.8	8
2,4-D	70		70				100				10	10	100
4,4-DDD								0.00083	0.00084	1 (s)		0.1	1
4,4-DDE								0.00059	0.00059	1 (s)		0.1	1
4,4-DDT								0.00059	0.00059	1 (s)		0.1	1
Endosulfan (I and II)							0.93		2				
Endrin	2		2				0.76 (p)		0.81		0.02	0.02	0.2
Heptachlor	0.01		0.4					0.00021	0.00021	0.1	0.008	0.47	4.7
Heptachlor epoxide	0.01		0.2					0.0001	0.00011	0.04			
Methoxychlor	40		40				100				10	10	100
Polychlorinated biphenyls	0.5		0.5					0.000044	0.000045	0.045		5	50
2,4,5-T													
Toxaphene	3		3					0.00073	0.00075	0.3	0.5	0.5	5
2,4,5-TP (Silvex)	50		50				10				1	1	10

Footnotes for Table B-2

† Chemical names and numeric criteria were taken from *A Compilation of Water Quality Goals* by Jon Marschack, 1995 (CRQCB), except where noted.

1 Maximum Contaminant Levels (MCLs) are drinking water quality standards established by the U.S. Environmental Protection Agency (U.S. EPA) under the Safe Drinking Water Act, the State of California under Domestic Water Quality and Monitoring Regulations (CCR Title 22, Chapter 15). Primary MCLs present risk to the human health when used for drinking or culinary pruposes, and secondary MCLs may be objectionable to an appreciable number of people but are not generally hazardous to human health

2 California "Action Levels" are advisory concentrations to water suppliers and are published by the California Department of Health Services (DHS) Office of Drinking Water. Toxic levels are based on a 10^{-6} incremental cancer risk level, while taste and odor (organoleptic) values are not health-based.

3 National Ambient Water Quality Criteria (NAWQC) are from the U.S. EPA Office of Health and Environmental Assessment. Non-cancer public health goals are based on known effects, and cancer risk levels are based on a one-in-a-million criteria

4 Human health risk based on fish consumption is from the U.S. EPA 40 CFR 131 *Water Quality Standards; Establishment of Numeric Criteria for Primary Toxic Pollutants; State Compliance;* Final Rule, Federal Register, Volume 57, No. 246 (Tuesday, 22 December 1992).

5 Proposition 65 was established by the California Environmental Protection Agency (Cal EPA), Office of Environmental Health Hazard Assessment (OEHHA) under the California Drinking Water and Toxic Enforcement Act of 1986 for known human carcinogens and reproductive toxins.

6 Feleral hazardous materials criteria: Toxicity Characteristic Leaching Procedure (TCLP) (40 CFR, Part 268, Appendix I).

7 Soluble Threshold Limit Concentration (STLC) is the leachable concentration based on California's Waste Extraction Test (WET) extraction procedures. If the leachate is less than the STLC, the waste is not considered hazardous and no further testing is required. If the wet weight concentration exceeds the Total Threshold Leaching Concentration (TTLC), the waste is considered hazardous. If the waste exceeds the STLC and is less than the TTLC, refer to CCR Title 22 for additional test procedures.

(a) MCL varies with air temperature; 2.4 mg/L (≤ 53.7°F); 2.2 mg/L (53.8–63.8°F); 2.0 mg/L (58.4–63.8°F); 1.8 mg/L (63.9–70.6°F); 1.6mg/L (70.7–79.2°F); and 1.4 mg/L (79.3–90.5°F).
(b) As nitrate (NO_3) in addition, MCL for total nitrate plus nitrite = 10,000 µg/L (as N).
(c) As nitrogen (N); in addition, MCL for total nitrate plus nitrite = 10,000 µg/L (as N).
(d) For total triholomethanes (sum of bromoform, bromodichloromethane, chloroform, and dibromochloromethane).
(e) Recommended level; Upper level = 500 mg/L; Short-term level = 600 mg/L.
(f) MCL includes this action level to be exceeded in no more than 10 percent of samples.
(g) Proposed.
(h) For sum of 1,2- and 1,3-dichlorobenzenes.
(i) For chlorinated systems.
(j) Determined not to pose a risk of cancer through ingestion (Title 22, CCR, Section 12707).
(k) Based on reproductive toxicity.
(l) Expressed as dissolved.
(m) Expressed as nitrogen.
(n) For sum of dichlorobenzenes.
(o) For sum of endrin and endrin aldehyde.
(p) For sum of carcinogenic polynuclear aromatic hydrocarbons.
(q) For sum of DDT, DDD, and DDE.
(r) Value set equal to the analytical Limit of Quantitation at the time the value was established.
* Santa Barbara County Leaking Underground Fuel Tank (LUFT) cleanup levels: soil 100 mg/kg TPH; groundwater = 1,000 µg/L TPH.

C SITE 13C IRA HEALTH AND SAFETY PLAN

1.0 SITE 13C IRA HEALTH AND SAFETY PLAN ADDENDUM

This Health and Safety Plan addendum summarizes pertinent health and safety information and procedures required to conduct field work at the Site 13 Cluster (13C). The site cluster consists of Advanced Ballistic Re-Entry Systems A (ABRES-A) Launch Complex (Site 13), ABRES-A Lake and downgradient paleochannel (Site 14), and Missile Silo 395 B (Site 28) at Vandenberg Air Force Base (AFB), California. This addendum is intended to augment the following documents: Installation Restoration Program Remedial Investigation/Feasibility Study (RI/FS) Health and Safety Plan (Jacobs Engineering Group, Inc. [JEG] 1993), the Tetra Tech, Inc. (Tetra Tech) Corporate Health and Safety Manual (Tetra Tech 1999), the Basewide Sampling and Analysis Plan (Tetra Tech 2003), Site-Specific Health and Safety Plan, Site 13, for drilling and field operations (Tetra Tech 1993), and previous training received by field participants The above-mentioned documents are available for review or reference at the Tetra Tech field trailer, located at the Agena Tank Farm Investigation-derived Waste Storage Area at Vandenberg AFB, and in the Tetra Tech Santa Barbara, California, office.

This document also addresses the regulatory requirement in 29 Code of Federal Regulations (CFR) 1910.120 (b)(4) and California Code of Regulations (CCR) 5192 (b)(4) regarding site-specific health and safety plans.

1.1 FACILITY DESCRIPTION

Vandenberg AFB is located on the south-central coast of California, approximately halfway between San Diego and San Francisco. The base covers approximately 98,000 acres in western Santa Barbara County and is headquarters for the 30th Space Wing. The primary mission of the 30th Space Wing at Vandenberg AFB is to launch and track satellites in space, test and evaluate America's intercontinental ballistic missile systems, and support aircraft operations in the western range. As a nonmilitary facet of operations, Vandenberg AFB is also committed to promoting commercial space launch ventures.

1.1.1 Demographics

Vandenberg AFB supports approximately 12,000 personnel, comprising Air Force personnel, civilian employees, contractors, and military dependents. Approximately 2,080 family housing units are located in the main cantonment area The nearby cities of Lompoc and Santa Maria have populations of 41,103 and 77,423, respectively.

1.1.2 Climate

The climate at Vandenberg AFB remains relatively mild and constant throughout the year. The prevailing wind direction is to the east and southeast. The climate is categorized as subtropical (Mediterranean), receiving modest precipitation during the winter months (December through March), and little or no precipitation the rest of the year.

The Vandenberg AFB 30th Weather Squadron compiles climatological data at the base. From 1952 through 1997, the annual rainfall at the airfield ranged from 4.00 inches to 28.40 inches, with an average of 14.16 inches. During California's most recent drought period (1984 through 1990), the annual rainfall at the Vandenberg AFB airfield averaged 9.93 inches. In 1995, 1996, 1998, and 1999, Vandenberg AFB received greater than average precipitation.

The average annual temperature, based on 1952 to 1997 Vandenberg AFB airfield data, is 57 degrees Fahrenheit (°F). Recorded low and high temperature extremes from 1952 through 1999 are 25°F and 100°F, respectively.

Spring, summer, and fall are characterized by northwesterly winds with speeds averaging 5 to 7 knots (6 to 9 miles per hour [mph]). During November, December, and January, the prevailing winds are from the east-southeast at speeds averaging 6 knots (7 mph).

1.1.3 Facility History

The site of Vandenberg AFB was first operated as a military installation (Camp Cooke Army Base) in 1941. From 1942 until the end of World War II, armored, infantry, and Air Force divisions trained there. A prisoner-of-war camp operated at Camp Cooke during World War II as well. Camp Cooke was deactivated in 1946 and most of the Base was leased for agricultural purposes. During the Korean conflict, the camp was reactivated until 1953.

In 1956, the Department of Defense selected Camp Cook as the site of the first Air Force missile base in the United States. In 1957, North Camp Cooke was transferred to the Air Force and designated Cooke AFB. The southern portion of the Army Base was assigned to the Navy and designated Point Arguello Naval Missile Facility. In 1958, Cooke AFB was renamed Vandenberg AFB. In 1964, the Point Arguello Naval Missile Facility was transferred to the Air Force.

1.1.4 Site-Specific Descriptions

Site 13 includes the ABRES-A Launch Complex, and a portion of ABRES-A Canyon to the south and west of the launch complex. The ABRES-A Launch Complex at Site 13 consists of a control center and three launch pads (Buildings 1788, 1790, and 1797). There are three deluge channels (Channels A, B, and C) extending from each of the launch pads at the ABRES-A launch complex that conveyed discharges toward ABRES-A Lake. Eighty-four Atlas missiles were launched from the ABRES-A Launch Complex between 1959 and 1974. The first Atlas missiles (Atlas D) were launched between 1959 and 1966 using "wet pad" technology. From 1964 to 1967, ABRES-A launch operations transitioned to Atlas E and F missiles, which used "dry pad" technology and no longer required using the deluge system. Chlorinated solvents, primarily TCE, were used on-site for degreasing missile engines and cleaning parts. A TCE storage tank was located within the launch service building at each pad of Site 13. Before regulations regarding use of solvents were implemented, TCE and possibly other solvents may have been released on-site.

Site 14 includes ABRES-A Lake, the western portion of ABRES-A Canyon and surrounding bluffs, the discharge point of an earthen drainage channel from Site 28 (Missile Silo 395-B), and the neutralization lagoon located on the north bluff of the canyon.

Site 28 was formerly used for launching Titan II missiles, which were fueled with the hypergolic fuels. Trace concentrations of hypergolic fuels were detected in one groundwater sample collected in 1994, but has not been detected since that time.

1.2 TRAINING / MEDICAL SURVEILLANCE REQUIREMENTS

Before performing any site work, all on-site personnel, including subcontractors, will have completed the medical surveillance and training requirements specified by the Tetra Tech Health and Safety Manual, Volume II, document control numbers 3-1/3-2 (Tetra Tech 1999), and 29 CFR 1910.120. At least one team member on-site must be certified in first aid and cardiopulmonary resuscitation (CPR). Before starting any work, each on-site person will acknowledge that he/she has read, understands, and will comply with the requirements of this plan by signing the Site Safety Plan Consent Agreement (Attachment C-1).

A daily tailgate health and safety meeting will be conducted before personnel sign the Daily Tailgate Safety Meeting Form (Attachment C-2), enter the site, and begin field work. This documentation will be submitted to the Project Manager/Site Safety Coordinator at the end of each field day

This site-specific health and safety plan is a certification of Hazard Assessment

1.3 EMERGENCY INFORMATION AND HEALTH AND SAFETY PERSONNEL

The location of Site 13 Cluster and the Lompoc Hospital are shown on Figure C-1. A first aid kit, eyewash, and fire extinguisher will be available during field operations. A cellular phone must be available on-site. Table C-1 provides emergency contact information.

1.3.1 Key Personnel

Division Health and Safety Manager: Chris McClain is responsible for overseeing Health and Safety Programs for the Tetra Tech organization. Ms. McClain can be reached at (626) 351-4664, extension 2542.

Project Health and Safety Manager: Jennifer Higgins is responsible for maintaining this plan, advising field staff on implementation of this plan, and conducting periodic inspections for compliance with this plan. Ms. Higgins can be reached at (805) 681-3100, extension 114.

Site Health and Safety Officer: David Fenity, or his designee, is responsible for field coordination of Health and Safety Programs and for implementation of the Health and Safety Plan at the site. This includes ensuring the proper use of personal protective equipment (PPE), enforcing safe work habits, and conducting a tailgate safety meeting before the start of field activities. These responsibilities also include conducting periodic safety inspections of all protective gear. Mr. Fenity can be reached in the office at (805) 681-3100, extension 124, and in the field by cellular phone. Call the Tetra Tech receptionist at (805) 681-3100 to obtain the cellular phone number.

Any member of the field crew is authorized to shut down the field operation based on any expressed concern until project management can be consulted.

1.3.2 Emergency Contingency Plans

In preparing for emergencies, each site worker will know where to get first aid, a fire extinguisher, a portable eye washer, the nearest telephone, and generally what to do in case of an emergency. Subcontractors are required to provide their own first aid kit. The map to the hospital will be attached to this Health and Safety Plan Addendum and prominently displayed on the dashboard of the Tetra Tech field vehicle after the tailgate safety meeting.

If the Site Health and Safety Officer deems the site unsafe for any reason, then personnel will evacuate the exclusion zone and contamination reduction zone and reconvene in the designated place of refuge. Emergency alerting will be conducted by voice or sign language and personnel will respond verbally or using sign language. If sign language is to be used, it will be reviewed during the tailgate safety meeting each day before starting work. Evacuation will be conducted by turning off power to equipment, decontaminating workers, and calmly leaving the work site. The place of refuge while performing field activities is the end of Watt Road. This area is over 500 feet upwind of the exclusion and contamination reduction zones. The Site Health and Safety Officer may designate an alternative place of refuge during the tailgate safety meeting, if appropriate

If an injury occurs, work will stop and heavy equipment will be turned off. The injured person will undergo decontamination to the extent necessary to ensure their safety and the safety of the rescue personnel, and first aid will be administered. If injuries require medical attention, the following steps will be implemented:

- Step 1 Call ambulance (land line 911/cell phone: 734-4117) or go to hospital first.
- Step 2 Call Tetra Tech office. Notify Kevin McNamara or Jennifer Higgins at (805) 681-3100, extensions 134 and 114, respectively.
- Step 3 Give the following information to Mr. McNamara or Ms. Higgins:

  a. Injury sustained;

  b. Location of the accident;

  c. Personnel involved; and

  d. Who has been contacted and what action has been taken (e.g., ambulance, hospital).

The nearest medical facility is Lompoc District Hospital, up to 45 minutes away. A map to the hospital is attached (Figure C-1). The hospital is located at 508 E. Hickory Avenue, on the corner of Hickory Avenue and D Street in Lompoc, California

1.4 HAZARDS OF CONCERN

1.4.1 Chemical Hazards

Refer to Table C-2 for a list of potential contaminants that may be encountered in soil or groundwater. The RI/FS Health and Safety Plan (JEG 1993) provides additional chemical hazard information for many of the contaminants that may be encountered. Table C-3 summarizes threshold limits including Short Term Exposure Limits (STELs) and Permissible Exposure Limits (PELs), where available, for potential site contaminants. Chemical hazard information is provided in Attachment C-3.

1.4.2 Activity and Physical Hazards

The RI/FS Health and Safety Plan (JEG 1993) and the Tetra Tech Corporate Health and Safety Manual (Tetra Tech 1999) provide additional information regarding safety procedures with respect to activity and physical hazards in the field. Activity and physical hazards include drilling and well installation, well sampling, preparing and injecting emulsified soybean oil (ESO), working with pressurized vessels and hoses, and underground and overhead utilities.

The use of heavy equipment for drilling, preparing and injecting ESO, debris removal, and lifting poses a great potential for physical injury to personnel. All vehicles will have spotters for backing maneuvers and traffic control. Only qualified personnel are allowed to operate heavy equipment. Operation of construction equipment during well installation and ESO injection may be the source of elevated noise levels. Therefore, the Site Health and Safety officer shall determine hearing protection based on the results of routine noise monitoring

Field personnel working with pressurized hoses and containers will be exposed to dangers related to impact and explosion. All personnel working around pressurized vessels and hoses will wear adequate PPE (Section 1-7) Uncontrolled contact of buried and overhead utilities, such as gas and electrical lines is a significant issue of concern Precautionary actions to take prior to commencing fieldwork include completing the Form 35 Permit which includes the coordination for fieldwork request (Basewide Sampling and Analysis Plan, Appendix A), maintaining appropriate distances from overhead utilities during drilling, and performing lockout, tag-out procedures on utilities that will be moved or directly impacted by drilling prior to beginning fieldwork.

Soil boring and sampling hazards may include, but are not necessarily limited to:

- Moving equipment parts;
- Lifting and carrying heavy equipment;
- Oral or dermal contact with potentially contaminated soils;
- Inhalation of potentially contaminated dust generated during drilling;
- Contact with poisonous plants (e g., poison oak), animals (e.g., rattlesnakes), or insects;
- Slips, trips, and falls from uneven terrain;
- On-site vehicular traffic in populated areas;
- Physical distress related to heat or cold; and
- Extreme weather conditions (e.g., lightning or wind).

To avoid injury from moving equipment parts, personnel will be properly trained before using sampling equipment. Personnel will obtain help from co-workers when heavy lifting is required. To avoid contact with contaminated soil, personnel will wear appropriate PPE. Personnel will exercise extreme caution when working in areas where poison oak, snakes, or uneven terrain are present. The best protection against poison oak is PPE, such as Tyvek (taped to boots and gloves), rubber boots, and inner and outer gloves. Whenever lightning is within 3 miles of the work area, site activities will be shut down. Physical hazards related to heat and cold are discussed below.

Hazards associated with drilling, IDW management, installation of the *In-situ* Submerged Oxygen Curtain (iSOC) system, and injection of fluids include noise and heavy equipment in addition to the ones listed above. Care will be taken to avoid the operating drill rig and the bucket of the front loader. Personnel will not approach the drill rig or walk behind the front loader without first notifying the equipment operator. Workers in close proximity will maintain visual contact with equipment operator at all times Hearing protection is required around noisy equipment. Dusts will be mitigated by spraying water on the dry soil. Non-essential personnel must remain in the support zone. For a more detailed list of heavy equipment hazards, see Use of Heavy Equipment, Safe Work Practice 6-26 in the Tetra Tech Corporate Health and Safety Manual (Tetra Tech 1999).

Hazards associated with contacting site soil result mostly from dermal absorption, ingestion, and inhalation of dusts. Personnel will wear PPE (e.g., Tyvek, gloves, safety glasses) to avoid unnecessary exposure to contaminants of concern during drilling or IDW soil management. Non-essential personnel will not handle soil and will stay in the support zone.

1.4.2.1 Heat Stress

Wearing PPE during warm weather puts employees at considerable risk of developing heat-related illness. Health effects from heat stress range from transient heat fatigue or rashes to serious illness (e.g., heat stroke) or death. Employees are instructed to recognize and treat heat-related illness during 8-hour health and safety refresher and first aid training courses. When working in hot environments, the following procedures will be implemented to reduce the risk of heat stress:

- Follow the buddy system and watch for signs of heat stress in co-workers.
- Implement work and rest cycles, as appropriate, to periodically allow employees to remove protective clothing and cool down.
- Regularly drink liquids to replace lost body fluids.
- Use cooling devices such as shade canopies, sun hats, ice vests, or fans, if necessary

Procedures for treating heat stress conditions and for monitoring heat stress are described in Volume III of the Tetra Tech Health and Safety Manual (Tetra Tech 1999).

1.4.2.2 Cold Exposure

Bare flesh and body extremities such as fingers, toes, and ears are most susceptible to wind chill or extremely low ambient temperatures. Employees are instructed to recognize and treat cold-related injuries during 8-hour health and safety refresher and first aid training courses. The two primary factors influencing the risk potential for cold stress are temperature and wind velocity. Wetness can also contribute to cold stress. Hypothermia can occur at temperatures above freezing if the individual is wearing wet or damp clothing. When working in cold environments, the following procedures will be implemented to lessen the chances of cold-related injuries:

- Protect exposed skin surfaces with appropriate insulating clothing such as face masks, gloves, and footwear
- Dress in layers to adapt to changing temperatures.
- Provide extra insulating clothing on-site.
- Reduce the duration of exposure to cold.
- Change wet or damp clothing as soon as possible

Procedures for evaluating the combined effect of temperatures and wind are described in Volume III of the Tetra Tech Health and Safety Manual (Tetra Tech 1999).

1.5 AIR MONITORING

Air monitoring will be conducted at the Site 13 Cluster to ensure worker safety during drilling and groundwater sampling. A flame ionization detector (FID) will be used for organic vapor screening.

Personnel will measure for organic vapors in the breathing zone with a FID a minimum of every half-hour during drilling activities. Personnel will measure organic vapor concentrations at the Site 13 Cluster in the breathing zone and record the results in the logbook.

If the FID reading is 5 parts per million (ppm) or more above background, personnel will allow the area to vent for a few minutes and then take another PID reading. Personnel will put on full-face respirators with organic vapor/acid gas cartridges and P100 filters (respiratory level C) if readings are more than 5 ppm above background in the breathing zone.

If FID readings are consistently 25 ppm or more above background in the breathing zone, then personnel will retreat to the support zone by Watt Road (see Section 1.6.3). Work will resume only after completion of a site-specific health and safety plan that addresses use of Level B PPE.

1.6 WORK ZONES

A minimum of three work zones (exclusion zone, contamination reduction zone, and support zone) will normally be established to ensure that:

- All personnel are properly protected against existing site hazards;
- Work activities and contaminants are confined to appropriate areas;
- Personnel can be controlled and evacuated in the event of an emergency;
- Potential routes and levels of possible contaminant dispersion can be evaluated; and
- Movement of personnel and equipment across these zones shall be minimized and restricted to specified areas and specific control points to prevent cross-contamination.

1.6.1 Exclusion Zone

Sampling personnel will establish an exclusion zone that is a 20-foot radius around the immediate drilling/injection/sampling and sampling equipment staging area. Because the Site 13 Cluster IRA area is remote, the exclusion zone does not require delineation with caution tape.

Equipment and PPE shall be cleaned of gross contamination prior to exiting the exclusion zone and entering the contamination reduction zone.

1.6.2 Contamination Reduction Zone

The contamination reduction zone is a transition area between the exclusion zone and support zone or clean area. Final decontamination operations are performed in the contamination reduction zone prior to entry to the support zone. The contamination control line separates the contamination reduction zone from the support zone.

1.6.3 Support Zone

The support zone is an uncontaminated or clean zone where workers should <u>not</u> be exposed to hazardous conditions. The support zone starts at the western edge of Watt Road, and the vicinity of wells 14-MW-6 and 14-MW-7. Typical activities included in this zone consist of:

- Interfacing with field teams, clients, and regulators;
- Eating and drinking; and
- Maintaining site security, PPE, supplies, and work vehicles.

Site visitors must remain in the support zone unless they obtain specific permission from the site safety officer to enter the contamination reduction zone or the exclusion zone Appropriate PPE must be put on before such an entry is made.

1.7 PERSONAL PROTECTIVE EQUIPMENT

1.7.1 General

Selection of the appropriate PPE is required before work can begin Key factors involved in this process are identifying known and suspected hazards or routes of entry, and effectiveness of the PPE in providing a barrier to these hazards. Appendix B to 29 CFR 1910.120 "General Description and Discussion of the Levels of Protection and Protective Gear" offers guidance regarding the specification and application of PPE. The PPE prescribed in the plan is based on this guidance

Personal protective equipment is divided into four categories based on the amount of protection it provides Level A is the highest level of protection and Level D is the lowest. Level D will be the most likely protection level used during the drilling, substrate injection, and groundwater sampling activities Levels A and B require self-contained breathing apparatus or supplied air. Level C requires air-purifying respirators. If vapor concentrations in the breathing zone are 5 ppm or more above background, Level C protection will be required Levels A and B are neither anticipated nor permissible under this project-specific Health and Safety Plan. If organic vapor concentrations measured with a FID are more than 25 ppm above background, requiring Level B protection, the work will immediately be stopped. The Project Health and Safety Manager will then be informed, approve use of Level B protection, and write a site-specific health and safety plan that addresses use of Level B PPE before work can be resumed at the site.

1.7.2 Minimum PPE

1.7.2.1 Minimum PPE for Drilling Activities

The level of protection prescribed under this plan is Level D. All personnel performing field work, including subcontractors will use Level D protection This protection will include, as a minimum:

- Work apparel appropriate for the task to be performed. This generally means a sleeved shirt and long pants;
- Steel-toed boots;
- Safety glasses or goggles (ANSI § 87 1);
- Hard hats when overhead hazards are present and in hard hat designated areas;
- Nitrile outer and inner gloves for handling potentially contaminated materials;
- A disposable dust mask or respirator with a minimum of a P100 filter during site work conditions when dust is present and persistent; and

- A respirator with an organic vapor/acid gas cartridge and a P100 filter during site work where organic vapors exceed the action level (5 ppm) but are less than 25 ppm

Because direct contact with contaminated soil is likely, disposable coveralls such as Tyvek, gloves, and safety glasses will be worn during drilling and sampling operations.

Visitors may use modified Level D PPE without gloves as long as they remain in the support zone.

1.7.2.2 Minimum PPE for iSOC Installation and Operation Activities

Subcontractors and personnel may come in contact with various hazards associated with the ISOC system during installation. Main hazards involve the movement of heavy objects and highly pressurized cylinders. When installing the iSOC systems, the minimum PPE required is:

- Steel-toed rubber boots;
- Safety face shield or glasses; and
- Hard hats (when overhead hazards are possible).

1.7.2.3 Minimum PPE for ESO Injection Activities

Subcontractors and personnel may come in contact with ESO during injection activities. Though ESO is food grade and non-toxic, the minimum PPE required is:

- Water-resistant work apparel appropriate for the task to be performed;
- Steel-toed rubber boots; and
- Hard hats.

1.7.3 Upgraded PPE

The level of protection will be upgraded from Level D to Level C when respiratory hazards of dust or organic vapors require this action. When monitoring equipment indicates elevated organic vapors in the work area, the Site Health and Safety Manager and his/her designee will take immediate action to:

- Warn the workers of this condition;
- Stop work if an action level has been reached or exceeded; and
- Decide to either upgrade PPE and continue work or stop work altogether if work cannot continue in a safe manner.

The PPE will then be upgraded to address the new condition. The readings from monitoring equipment and actions taken will be documented.

1.7.4 PPE requirements

The chart below is a simplified description of the PPE requirement. The default PPE specification is Level D

LEVEL C	*Modified Level C—no skin hazards*	*Standard Level C—skin hazards present*
Respiratory hazards present	• Air-purifying respirator, full face • Modified Level D equipment	• Air-purifying respirator, full face, for organic vapor hazards • All standard Level D equipment
LEVEL D	***Modified Level D—no skin hazards***	***Standard Level D—skin hazards present***
No respiratory hazards	• Long pants, sleeved shirt • Steel-toed boots • Safety glasses • Nitrile outer gloves with liner • Hard hat, when appropriate	• Chemical resistant coveralls, e.g., Tyvek • Steel-toed boots • Safety glasses • Nitrile outer gloves with liner • Hard hat, when appropriate

1.8 DECONTAMINATION

1.8.1 Personal Protective Equipment

Disposable PPE will be changed daily, decontaminated with Alconox soap and water, and placed in the domestic trash. Gross contamination on PPE, including boots, will be removed in the exclusion zone using Alconox soap and water. PPE will be final-cleaned and removed in the contamination reduction zone.

1.8.2 Equipment and Materials

Tools, sampling equipment, and other related materials will be decontaminated in the exclusion zone. Decontamination will consist of scrubbing equipment with a brush and potable water and Alconox solution until all visible contamination is removed, and rinsing twice with potable water. Equipment will be additionally rinsed with Type II reagent water when it will be used for sampling. Heavy equipment will be cleaned of gross contamination in the exclusion zone and thoroughly decontaminated with soap and water at the central staging area. The central staging area will be west of Watt Road while drilling is under way.

1.8.3 Decontamination Solutions

Decontamination water will be stored in a portable tank and transported to a holding tank at the Agena Tank Farm. The holding tank will be sampled at the Agena Tank Farm and analyzed for contaminants of concern. Based on analytical results, decontamination solutions will be disposed of appropriately.

1.8.4 Personal Hygiene

All on-site personnel will maintain good hygiene practices. On-site personnel will wash hands and face immediately upon completion of site activities. Smoking, eating, and drinking are allowed only in the support zone. Personnel must wash their hands and face before smoking, eating, or drinking.

2.0 REFERENCES

Jacobs Engineering Group, Inc. (JEG)

1993 *Installation Restoration Program Remedial Investigation/Feasibility Study Health and Safety Plan, Vandenberg Air Force Base, California.* Prepared for 730 CES/CEVR Installation Restoration Program, Vandenberg Air Force Base, California, 93437, and Headquarters Air Force Space Command (HQ AFSPACECOM), Peterson Air Force Base, Colorado.

Tetra Tech, Inc. (Tetra Tech)

1993 *Site Specific Health and Safety Plan, Site 13, Installation Restoration Program, Vandenberg Air Force Base, California,* Headquarters Air Force Space Command.

Tetra Tech, Inc. (Tetra Tech)

1999 *Tetra Tech Corporate Health and Safety Manual.*

Tetra Tech, Inc. (Tetra Tech)

2003 *Final Vandenberg AFB Basewide Sampling and Analysis Plan to Installation Restoration Program Remedial Investigation/Feasibility Study, Sampling and Analysis Plan for Operable Units 1, 2, 3B, 4, and 5, Vandenberg Air Force Base, California* (JEG 1993). Prepared for 30 CES/CEV Installation Restoration Program, Vandenberg Air Force Base, California, and Headquarters Air Force Space Command, Peterson Air Force Base, Colorado.

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TABLES

Table C-1
Emergency Resource Information

Local/Site Resources	Name	Phone
Police	VAFB Security	911/cell phone: 805-606-3911
Ambulance	VAFB Emergency	911/cell phone: 805-734-4117
Fire	VAFB Fire Emergency	911/cell phone: 805-734-4117
Division Health and Safety Manager	Chris McClain	626-351-4664 x 2542
Project Health and Safety Manager	Jennifer Higgins	805-681-3100 x 114
Site Health and Safety Officer	Matt Peterson	805-681-3100 x 112 cell phone: 805-455-5064
Project Manager	David Springer	805-681-3100 x 162
Site Superintendent	Dave Fenity	805-681-3100 x 124 cell phone: 805-455-0608
AFCEE COR	Kathleen Gerber	805-606-9834
VAFB IRP Site Manager	Andrew Edwards	805-605-8684
Medical Advisor/Client Rep.	Work Care	800-455-6155
Poison Information		800-764-7661
CHEMTREC		800-424-9300
Center for Disease Control		404-639-3534
National Response Center		800-424-8802
HAZMAT Spill Response Team Beeper		805-169-1035
Other(s)(HAZMAT Response)	Joe Parker, A.J. Diani	805-925-9533

Table C-2
Potential Contaminants of Concern
IRP Site 13 Cluster, OU4
Vandenberg AFB, California

IRP Site Number and Description	Site Description	Chemicals of Potential Concern
13 Cluster	Soil	Metals (As, Cd, Co, Pb, Mo, Ni, Se, Zn)
ABRES-A Canyon		*cis*-1,2-Dichloroethene
		Chloroform
		1,1,1-Trichloroethane
		Trichloroethene
		Total petroleum hydrocarbons as diesel
	Groundwater	Metals (As, Cd, Cu, Co, Hg, Fe, Mg, Mn, Mo, Ni, Pb Se, Tl, Zn)
		1,1-Dichloroethene
		cis-1,2-Dichloroethene
		trans-1,2-Dichloroethene
		TCE
		Vinyl chloride
		Carbon disulfide
		Acetone
		4-Methyl 2-pentanone
		Methyl ethyl ketone

Metals:

As	- Arsenic
Cd	- Cadmium
Co	- Cobalt
Cu	- Copper
Fe	- Iron
Hg	- Mercury
Pb	- Lead
Mo	- Molybdenum
Mg	- Magnesium
Mn	- Manganese
Ni	- Nickel
Se	- Selenium
Tl	- Thallium
Zn	- Zinc

Table C-3
Contaminants of Concern with Threshold Limit Values and Permissible Exposure Levels
IRP Site 13 Cluster, OU4
Vandenberg AFB, California

Contaminant of Concern	Form	PEL[1]		STEL[1]	
Arsenic	Arsenic and inorganic arsenic compounds	0.01	mg/m^3	N/A	
Cadmium	Metal dust	0.005	mg/m^3	N/A	
	Soluble salts	0.005	mg/m^3	N/A	
Cobalt	Metal fumes and dust	0.02	mg/m^3	N/A	
Copper	Metal fumes	0.01	mg/m^3	N/A	
	Salts, dust, and mist	1	mg/m^3	N/A	
Iron	Soluble iron salts	1.0	mg/m^3	N/A	
Lead	Dust and fume	0.05	mg/m^3	N/A	
Manganese	Manganese and compounds as Mn	0.2	mg/m^3	N/A	
Magnesium	Magnesium oxide fume	10.0	mg/m^3	3	mg/m^3
Mercury	Alkyls as Hg	0.01	mg/m^3	0.03	mg/m^3
	As vapor	0.05	mg/m^3	N/A	
	Inorganic compounds	0.01	mg/m^3	N/A	
Molybdenum	Metal, insoluble	10.0	mg/m^3	N/A	
	Soluble compounds	5	mg/m^3	N/A	
Nickel	Insoluble	1	mg/m^3	N/A	
	Soluble	0.1	mg/m^3	N/A	
Selenium	Selenium compounds as Se	0.2	mg/m^3	N/A	
Thallium	Soluble compounds as Tl	0.1	mg/m^3	N/A	
Zinc	Fumes	5.0	mg/m^3	N/A	
	Dust	10.0	mg/m^3	N/A	
1,1-Dichloroethene		1	ppm	N/A	
cis-1,2-Dichloroethene		200	ppm	N/A	
trans-1,2-Dichloroethene		200	ppm	N/A	
1,1,1-Trichloroethane		350	mg/m^3	450	ppm
Trichloroethene		25	ppm	100	ppm
Vinyl chloride		1	ppm	N/A	
Carbon Disulfide		4	ppm	12	ppm
Acetone		750	ppm	3000	ppm
4-methyl 2-pentanone		50	ppm	75	ppm
Methyl Ethyl Ketone		200	ppm	300	ppm

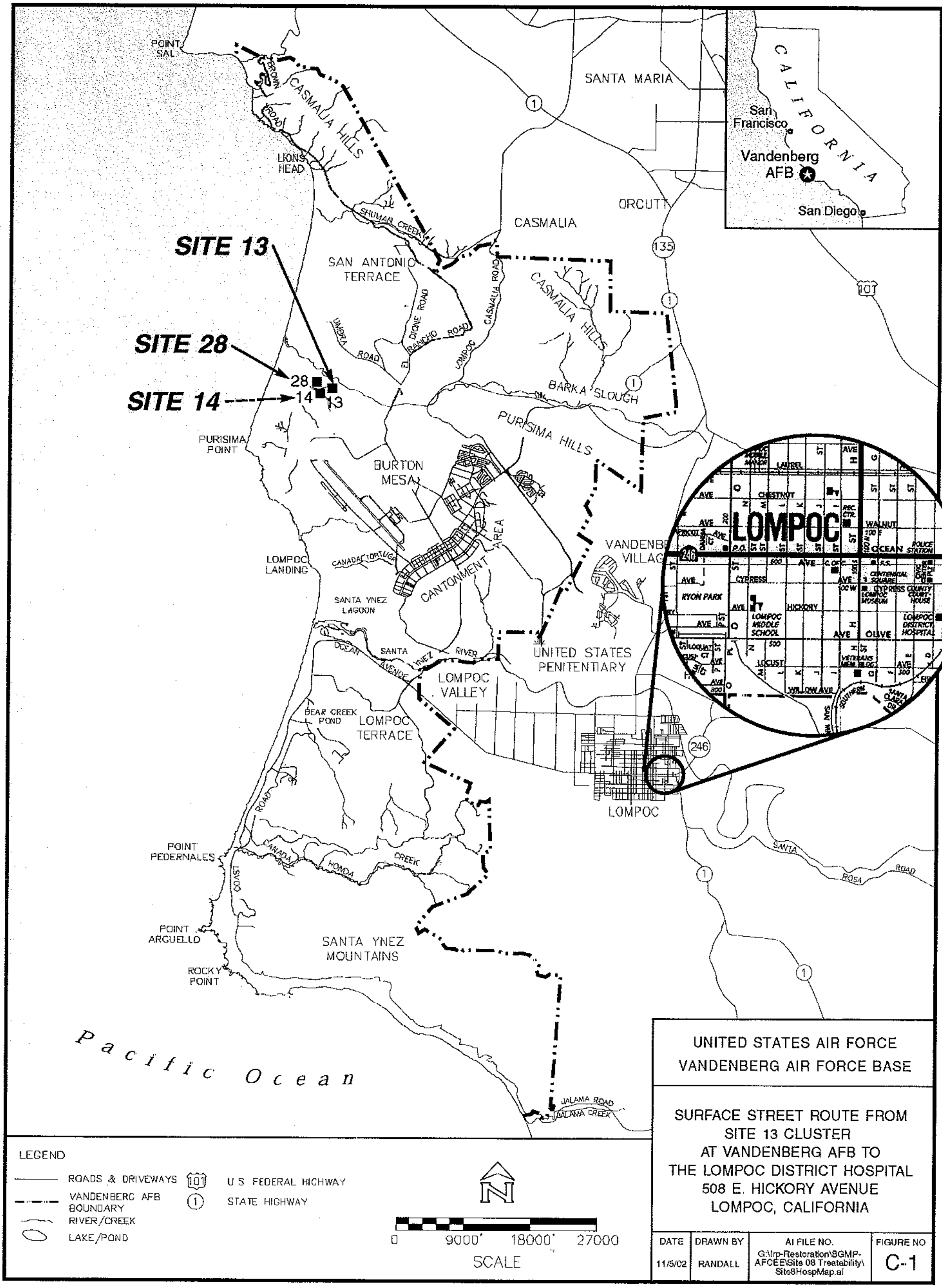
Definitions:

mg/m^3 - milligrams per cubic meter
N/A - not applicable
PEL - Permissible Exposure Limit
ppm - parts per million
STEL - Short Term Exposure Limit

Note(s):

1 - California Code of Regulations, Title 8, Section 5155 Airborne Contaminants

FIGURES



UNITED STATES AIR FORCE
VANDENBERG AIR FORCE BASE

SURFACE STREET ROUTE FROM SITE 13 CLUSTER AT VANDENBERG AFB TO THE LOMPOC DISTRICT HOSPITAL 508 E. HICKORY AVENUE LOMPOC, CALIFORNIA

DATE	DRAWN BY	AI FILE NO.	FIGURE NO
11/5/02	RANDALL	G:\Irp-Restoration\BGMP-AFCEE\Site 08 Treatability\Site8HospMap.ai	C-1

ATTACHMENTS

Tetra Tech, Inc.	ATTACHMENT C-1 SITE SAFETY PLAN CONSENT AGREEMENT Form 5.3-3

I have reviewed the Tetra Tech, Inc., Site Safety Plan for _Site 13C IRA_. I understand its contents and purpose and consent to adhere to its policies, procedures, and guidelines while an employee of Tetra Tech or its subcontractors.

Employee Name (Print)	Employee (Signature)	Company (Print)	Date

ATTACHMENT C-2
TETRA TECH, INC
DAILY TAILGATE SAFETY MEETING FORM

Date:________________ Time: _________________ Project No.: __________________

Client: _____________________________________ Site Location: ____________________________

Site Activities Planned for Today: ____

____

Safety Topics Discussed
Protective clothing and equipment:
Chemical hazards:
Physical hazards:
Environmental and biohazards:
Equipment hazards:
Decontamination procedures:
Other:
Review of emergency procedures:
Employee Questions or Comments:

C-3 CHEMICAL HAZARD INFORMATION

D CALCULATIONS

Table D-1
Site 13 Cluster Cost Estimate Summary Table

Alternative	Period of Performance	Cost	Present Worth
Alternative 3A: HRC-X Injection	16 Years	$9,218,095	$6,664,201
Alternative 3B: HRC-X and ORC Injection	16 Years	$7,329,584	$5,021,935
Alternative 3C: iSOC Gaseous Diffusion	16 Years	$4,009,884	$2,928,720
Alternative 3D: Soybean Oil Injection	16 Years	$3,466,231	$2,525,025
Alternative 3E: iSOC Gaseous Diffusion and Soybean Oil	16 Years	$3,621,636	$2,642,404
Alternative 4: In-Situ Chemical Oxidation	16 Years	$8,358,146	$5,468,716
Alternative 5: Ex-Situ Groundwater Treatment	16 Years	$6,316,237	$4,680,810

Table D-2
Site 13 Cluster IRA Cost Estimate
For Alternative 3A: Injection of HRC-X
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	ea	40	$80,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$270,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Well Installation + Oversight	$878,773	LS	1	$878,773	Table C-9	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$906,273		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
Substrate Injection at Watt Road	$499,224	ea	1	$499,224	Table C-11	Vendor Quote
Substrate Injection at Railroad	$729,190	ea	1	$729,190	Table C-12	Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	2	$2,400		Engineering Estimate
SUBTOTAL				$1,251,733		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,832	Table C-17	Engineering Estimate
Substrate Reinjection (HRC-X every 3 yrs) Watt Road	$499,224	ea	5	$2,496,119	Table C-11	Vendor Quote
Substrate Reinjection (HRC-X every 3 yrs) Railroad Tracks	$729,190	ea	2	$1,458,380	Table C-12	Vendor Quote
SUBTOTAL				$4,653,331		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Data Management	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$982,800		
SUBTOTALS				$8,015,735		
15% contingency				$1,202,360		
TOTAL PROGRAM				**$9,218,095**		
Present Value				$6,664,201	Table C-20	

Table D-3
Site 13 Cluster IRA Cost Estimate
For Alternative 3B: Injection of HRC-X and ORC
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	ea	40	$80,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$270,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
HRC Injection + Monitoring Well Installation + Oversight	$483,819	LS	1	$483,819	Table C-10	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$511,319		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
ORC Substrate injection Railroad Tracks	$226,389	LS	1	$226,389	Table C-13	Vendor Quote
HRC-X Substrate Reinjection Watt Road	$499,224	LS	1	$499,224	Table C-11	Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	3	$3,600		Engineering Estimate
SUBTOTAL				$757,677		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,832	Table C-17	Engineering Estimate
Substrate Reinjection (ORC every 2 yrs) Railroad Tracks	$226,389	ea	3	$679,167	Table C-13	Vendor Quote
Substrate Reinjection (HRC-X every 3 yrs) Watt Road	$499,224	ea	5	$2,496,119	Table C-11	Vendor Quote
SUBTOTAL				$3,896,753		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Data Management (quarterly)	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$982,800		
SUBTOTALS				$6,373,552		
15% contingency				$956,033		
TOTAL PROGRAM				**$7,329,584**		
Present Value				$5,021,935	Table C-20	

Table D-4
Site 13 Cluster IRA Cost Estimate
For Alternative 3C: iSOC
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	ea	40	$80,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$270,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Well Installation + Oversight	$878,905	LS	1	$878,905	Table C-14	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$906,405		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
iSOC Unit Purchase (per well)	$5,000	ea	30	$150,000	Appendix C.3	Vendor Quote
Gas Cylinder	$300	ea	30	$9,000		Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	8	$9,600		Engineering Estimate
SUBTOTAL				$189,519		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,832	Table C-17	Engineering Estimate
iSOC Unit Repair/Gas Replacement - Watt Road	$5,000	LS	15	$75,000		Vendor Quote + Engineering Estimate
Cylinder refill (bimonthly)	$100	ea	1440	$144,000		Engineering Estimate
iSOC Unit Repair/Gas Replacement - Railroad Tracks	$5,000	LS	7.5	$37,500		Vendor Quote + Engineering Estimate
Cylinder refill (bimonthly)	$100	ea	540	$54,000		Engineering Estimate
Labor and Oversight	$2,000	LS	64	$128,000		Engineering Estimate
SUBTOTAL				$1,137,332		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Data Management (quarterly)	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$982,800		
SUBTOTALS				$3,486,856		
15% contingency				$523,028		
TOTAL PROGRAM				**$4,009,884**		
Present Value				$2,928,720	Table C-20	

Table D-5
Site 13 Cluster IRA Cost Estimate
For Alternative 3D: Soybean Oil
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	ea	40	$80,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$270,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Well Installation + Oversight	$878,773	LS	1	$878,773	Table C-9	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$906,273		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
Substrate (Soybean Oil + emulsifier)	$28,597	LS	1	$28,597	Appendix C.4	Vendor Quote
Vironex-injection	$3,100	day	3	$9,300		Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	3	$3,600		Engineering Estimate
SUBTOTAL				$62,416		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,832	Table C-17	Engineering Estimate
Substrate Reinjection (Soybean Oil every 4 yrs) Watt Road	$14,299	ea	4	$57,194		Vendor Quote
Substrate Reinjection (Soybean Oil every 4 yrs) Railroad Tracks	$14,299	ea	1	$14,299		Vendor Quote
Reinjection Labor and Oversight	$4,300	LS	5	$21,500		Engineering Estimate
SUBTOTAL				$791,825		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Data Management (quarterly)	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$982,800		
SUBTOTALS				$3,014,114		
15% contingency				$452,117		
TOTAL PROGRAM				**$3,466,231**		
Present Value				$2,525,025	Table C-20	

Table D-6
Site 13 Cluster IRA Cost Estimate
For Alternative 3E: iSOC and Soybean Oil
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	ea	40	$80,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$270,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Well Installation + Oversight	$878,905	LS	1	$878,905	Table C-15	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$906,405		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
Watt Road Substrate (Soybean Oil + emulsifier)	$14,299	LS	1	$14,299	Appendix C.4	Vendor Quote
Watt Road Vironex-injection	$3,100	day	2	$6,200		Engineering Estimate
iSOC Unit Purchase (per well)	$5,000	ea	15	$75,000	Appendix C.3	Vendor Quote
Gas Cylinder	$300	ea	15	$4,500		Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	3	$3,600		Engineering Estimate
SUBTOTAL				$124,518		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,832	Table C-17	Engineering Estimate
Substrate Reinjection (Soybean Oil every 4 yrs) Watt Road	$14,299	ea	4	$57,194		Vendor Quote
iSOC Unit Repair/Gas Replacement - Railroad Tracks	$5,000	LS	7.5	$37,500		Vendor Quote + Engineering Estimate
Cylinder refill (bimonthly)	$100	ea	540	$54,000		Engineering Estimate
Reinjection Labor and Oversight	$4,300	LS	4	$17,200		Engineering Estimate
SUBTOTAL				$864,726		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Data Management (quarterly)	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$982,800		
SUBTOTALS				$3,149,249		
15% contingency				$472,387		
TOTAL PROGRAM				**$3,621,636**		
Present Value				$2,642,404	Table C-20	

Table D-7
Site 13 Cluster IRA Cost Estimate
For Alternative 4: In-Situ Chemical Oxidant
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	8	40	$16,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$206,800		
Field Task 1 - Pilot Test/Well Install	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Well Installation + Oversight	$861,129	LS	1	$861,129	Table C-16	Vendor quote + estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Bench Column Testing	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$888,629		
Field Task 2 - Substrate Injection + Baseline	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Site Preparation/grading	$10,000	LS	1	$10,000		Engineering Estimate
Substrate (Permanganate)	$2.00	lb	28,615	$57,230	Appendix C.5	Engineering Estimate
Vironex-injection	$3,100	day	8	$24,800		Engineering Estimate
Baseline Monitoring	$10,919	LS	1	$10,919		Engineering Estimate
Labor and oversight	$1,200	day	10	$12,000		Engineering Estimate
SUBTOTAL				$114,949		
Field Task 3 - Operations & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$10,919	qtr	64	$698,816	Table C-17	Engineering Estimate
Substrate Purchase (Every 120 Days) Watt Road	$51,530	ea	48	$2,456,263		Engineering Estimate
Substrate Purchase (Every 120 Days for the first 6 years) Railroad	$5,700	ea	18	$104,025		Engineering Estimate
Vironex Injection, Watt Road	$3,100	day	381	$1,182,133		Engineering Estimate
Vironex Injection, Railroad (first 6years)	$3,100	day	18	$56,575		Engineering Estimate
Labor and Oversight	$12,000	LS	48	$572,000		Engineering Estimate
IDW (Oxidant)	$1,000	ea	48	$47,667		Engineering Estimate
SUBTOTAL				$5,117,479		
Field Task 4 - Reporting	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Reports	$10,689	qtr	64	$684,096	Table C-19	Engineering Estimate
Data Management (quarterly)	$3,500	qtr	64	$224,000		Engineering Estimate
IDW	$500	ea	64	$32,000		Engineering Estimate
SUBTOTAL				$940,096		
SUBTOTALS				$7,267,953		
15% contingency				$1,090,193		
TOTAL PROGRAM				**$8,358,146**		
Present Value				$5,468,716	Table C-20	

Table D-8
Site 13 Cluster IRA Cost Estimate
For Alternative 5: Ex-Situ Groundwater Treatment
16 Year POP

	Unit Price	Unit	Quantity	Extended Cost	Basis or Comments	Source
Project Management	$2,200	qtr	64	$140,800	Quarterly CPSMR	Engineering Estimate
Meetings	$2,000	8	40	$16,000		Engineering Estimate
Removal Action Work Plan	$50,000	LS	1	$50,000		Engineering Estimate
SUBTOTAL				$206,800		
Field Task 1 - Pilot Program	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Permitting	$2,500	LS	1	$2,500		Engineering Estimate
Pump Test	$20,000	LS	2	$40,000		Engineering Estimate
Geologist - Jr. Level (field)	$900	day	20	$18,000		Engineering Estimate
Hydrogeologist - Sr Level (field)	$1,100	day	5	$5,500		Engineering Estimate
Data Analysis/Modeling	$15,000	LS	1	$15,000		Engineering Estimate
Analytical	$5,000	LS	1	$5,000		Engineering Estimate
IDW	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$96,000		
Field Task 2 - System Installation	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Bids and Procurement	$10,000	LS	1	$10,000		Engineering Estimate
Permitting	$20,000	LS	1	$20,000		Engineering Estimate
Treatment Pad	$20,000	LS	2	$40,000		Engineering Estimate
Pumps/install	$2,000	ea	16	$32,000		Vendor Quote + Eng. estimate
Well/Install (incl. Oversight)	$878,773	LS	1	$878,773	Table C-9	Engineering Estimate
Piping installation	$85,000	LS	2	$170,000		Engineering Estimate
Electrical and Controls	$75,000	LS	2	$150,000		Engineering Estimate
Tanks, process units, GAC units	$50,000	LS	2	$100,000		Engineering Estimate
Engineer - Jr. Level (field)	$900	day	60	$54,000		Engineering Estimate
Hydrogeologist - Sr Level (field)	$1,100	day	20	$22,000		Engineering Estimate
Construction Superintendent - Sr Level (field)	$1,100	day	120	$132,000		Engineering Estimate
IDW Removal	$30,000	LS	1	$30,000		Engineering Estimate
IDW Analysis	$5,000	LS	1	$5,000		Engineering Estimate
Start Up/Shakedown	$50,000	LS	1	$50,000		Engineering Estimate
Surveying	$10,000	LS	1	$10,000		Engineering Estimate
SUBTOTAL				$1,703,773		
Field Task 3 - Operation & Maintenance	Unit Price	Unit	Units	Extended Cost	Basis or Comments	Source
Quarterly Monitoring	$13,334	qtr	64	$853,392	Table C-18	Engineering Estimate
Quarterly Reports	$11,356	qtr	64	$726,800	Table C-19	Engineering Estimate
Quarterly O&M Labor (2 persons)	$10,000	qtr	64	$640,000		Engineering Estimate
Carbon Replacement Watt Road (Liquid)	$1.65	lbs.	504255	$832,020	Appendix C.6	Vendor Quote
Carbon Replacement Railroad Track (Liquid)	$1.65	lbs.	85815	$141,595	Appendix C.6	Vendor Quote
IDW	$3,000	LS	64	$192,000		Engineering Estimate
SUBTOTAL				$3,385,807		
As-Builts, Final Design, Report	$100,000	LS	1	$100,000		Engineering Estimate
SUBTOTALS				$5,492,380		
15% contingency				$823,857		
TOTAL PROGRAM				**$6,316,237**		
Present Value				$4,680,810	Table C-20	

Table D-9
Site 13 Cluster Groundwater IRA: Installation of 27 Wells
For Alternatives 3A, 3D and 5

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	23.8	$750	day	$17,813
Geologist - Jr. Level (field)	95.0	$900	day	$85,500
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	9.5	$1,100	day	$10,450
Project Manager	4.8	$1,300	day	$6,175
SUBTOTAL				$120,938
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	119	$50	day	$5,938
Monitoring instruments	95	$40	day	$3,800
Phone	95	$5	day	$475
Micropurge Pumps	5	$2,500	ea	$12,500
SUBTOTAL				$22,713
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$100
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,500	LS	$4,500
Inj/Ext Well installation	27	$18,700	ea	$504,900
Mont Well Install	5	$18,700	ea	$93,500
IDW	1	$15,000	LS	$15,000
IDW Analytical	1	$2,500	LS	$2,500
SUBTOTAL				$620,400
SUBTOTALS				**$764,150**
15% Management & Administration Contingency				$114,623
PROJECT TOTAL				**$878,773**

Table D-10
Site 13 Cluster Groundwater IRA: Installation of 12 Wells
For Alternatives 3B at Watt Road

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	12.0	$750	day	$9,000
Geologist - Jr. Level (field)	45.0	$900	day	$40,500
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	4.5	$1,100	day	$4,950
Project Manager	2.3	$1,300	day	$2,925
SUBTOTAL				$58,375
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	56	$50	day	$2,813
Monitoring instruments	45.0	$40	day	$1,800
Phone	45.0	$5	day	$225
Micropurge Pumps	5	$2,500	ea	$12,500
SUBTOTAL				$17,338
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$100
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,000	LS	$4,000
Inj Well installation	12	$18,700	ea	$224,400
Mont Well Install	5	$18,700	ea	$93,500
IDW	1	$20,000	LS	$20,000
IDW Analytical	1	$3,000	LS	$3,000.00
SUBTOTAL				$344,900
SUBTOTALS				**$420,713**
15% Management & Administration Contingency				$63,107
PROJECT TOTAL				**$483,819**

Table D-11
Site 13 Cluster Groundwater IRA: Injection of HRC-X at Watt Road Location
For Alternatives 3A and 3B

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	8.0	$750	day	$6,000
Geologist - Jr. Level (field)	32.0	$900	day	$28,800
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	3.2	$1,100	day	$3,520
Project Manager	1.6	$1,300	day	$2,080
SUBTOTAL				$41,400
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	40	$50	day	$2,000
Monitoring instruments	32.0	$40	day	$1,280
Phone	32.0	$5	day	$160
SUBTOTAL				$3,440
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
HRC-X (Regenesis)	35,100	$8.3	ea	$292,427
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$292,527
Subcontractors	Qty	Unit Price	Unit	Extended Cost
HRC-X Injection (Vironex)	29.25	$3,100	ea	$90,675
IDW	1	$5,000	LS	$5,000
IDW Analytical	1	$3,000	LS	$3,000.00
SUBTOTAL				$98,675
SUBTOTALS				**$434,108**
15% Management & Administration Contingency				$65,116
PROJECT TOTAL				**$499,224**

Table D-12
Site 13 Cluster Groundwater IRA: Injection of HRC-X at Railroad Location
For Alternative 3A

Item	**Quantity**	**Unit Price**	**Unit**	**Extended Cost**
Labor				
Engineering Technician (field)	12.0	$750	day	$9,000
Geologist - Jr. Level (field)	48.0	$900	day	$43,200
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	4.8	$1,100	day	$5,280
Project Manager	2.4	$1,300	day	$3,120
SUBTOTAL				$61,600
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	60	$50	day	$3,000
Monitoring instruments	48.0	$40	day	$1,920
Phone	48.0	$5	day	$240
SUBTOTAL				$5,160
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
HRC-X (Regenesis)	52,800	$8.1	ea	$425,700
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$425,800
Subcontractors	Qty	Unit Price	Unit	Extended Cost
HRC-X Injection (Vironex)	44	$3,100	ea	$136,400
IDW	1	$5,000	LS	$5,000
IDW Analytical	1	$3,000	LS	$3,000.00
SUBTOTAL				$144,400
SUBTOTALS				**$634,078**
15% Management & Administration Contingency				$95,112
PROJECT TOTAL				**$729,190**

Table D-13
Site 13 Cluster Groundwater IRA: Installation of 15 ORC Injection Borings
For Alternative 3B

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	5.8	$750	day	$4,313
Geologist - Jr. Level (field)	23.0	$900	day	$20,700
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	2.3	$1,100	day	$2,530
Project Manager	1.2	$1,300	day	$1,495
SUBTOTAL				$30,038
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	29	$50	day	$1,438
Monitoring instruments	23.0	$40	day	$920
Phone	23.0	$5	day	$115
SUBTOTAL				$2,473
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
ORC Slurry (Regenesis)	1575	$10.0	ea	$15,750
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$15,850
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,000	LS	$4,000
Injection borings (drilling)	15	$6,000	ea	$90,000
HRC-X Injection (Vironex)	15	$3,100	ea	$46,500
IDW	1	$5,000	LS	$5,000
IDW Analytical	1	$3,000	LS	$3,000.00
SUBTOTAL				$148,500
SUBTOTALS				**$196,860**
15% Management & Administration Contingency				$29,529
PROJECT TOTAL				**$226,389**

Table D-14
Site 13 Cluster Groundwater IRA: Installation of 27 Wells
For Alternatives 3C

Item	**Quantity**	**Unit Price**	**Unit**	**Extended Cost**
Labor				
Engineering Technician (field)	23.8	$750	day	$17,850
Geologist - Jr. Level (field)	95.0	$900	day	$85,500
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	9.5	$1,100	day	$10,450
Project Manager	4.8	$1,300	day	$6,240
SUBTOTAL				$121,040
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	119	$50	day	$5,950
Monitoring instruments	95	$40	day	$3,800
Phone	95	$5	day	$475
Micropurge Pumps	5	$2,500	ea	$12,500
SUBTOTAL				$22,725
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$100
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,500	LS	$4,500
Inj/Ext Well installation	27	$18,700	ea	$504,900
Mont Well Install	5	$18,700	ea	$93,500
IDW	1	$15,000	LS	$15,000
IDW Analytical	1	$2,500	LS	$2,500
SUBTOTAL				$620,400
SUBTOTALS				**$764,265**
15% Management & Administration Contingency				$114,640
PROJECT TOTAL				**$878,905**

Table D-15
Site 13 Cluster Groundwater IRA: Installation of 27 Wells
For Alternative 3E

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	23.8	$750	day	$17,850
Geologist - Jr. Level (field)	95.0	$900	day	$85,500
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	9.5	$1,100	day	$10,450
Project Manager	4.8	$1,300	day	$6,240
SUBTOTAL				$121,040
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	119	$50	day	$5,950
Monitoring instruments	95	$40	day	$3,800
Phone	95	$5	day	$475
Micropurge Pumps	5	$2,500	ea	$12,500
SUBTOTAL				$22,725
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$100
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,500	LS	$4,500
Inj/Ext Well installation	27	$18,700	ea	$504,900
Mont Well Install	5	$18,700	ea	$93,500
IDW	1	$15,000	LS	$15,000
IDW Analytical	1	$2,500	LS	$2,500
SUBTOTAL				$620,400
SUBTOTALS				**$764,265**
15% Management & Administration Contingency				$114,640
PROJECT TOTAL				**$878,905**

Table D-16
Site 13 Cluster Groundwater IRA: Installation of 27 Wells
For Alternative 4

Item	**Quantity**	**Unit Price**	**Unit**	**Extended Cost**
Labor				
Engineering Technician (field)	18.4	$750	day	$13,800
Geologist - Jr. Level (field)	73.5	$900	day	$66,150
AutoCAD/Graphics	2.0	$500	day	$1,000
Hydrogeologist - Sr Level (field)	7.4	$1,100	day	$8,140
Project Manager	3.7	$1,300	day	$4,810
SUBTOTAL				$93,900
Equipment	Qty	Unit Price	Unit	Extended Cost
Field truck	92	$50	day	$4,600
Monitoring instruments	73.5	$40	day	$2,940
Phone	73.5	$5	day	$368
Micropurge Pumps	5	$2,500	ea	$12,500
SUBTOTAL				$20,408
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	1000	$0.07	pg	$70
Fed-Ex	2	$15.0	ea	$30
SUBTOTAL				$100
Subcontractors	Qty	Unit Price	Unit	Extended Cost
Surveyor	1	$4,000	LS	$4,000
Inj/Ext Well installation with steel casing	22	$22,700	ea	$499,400
Mont Well Install with steel casing	5	$22,700	ea	$113,500
IDW	1	$15,000	LS	$15,000
IDW Analytical	1	$2,500	LS	$2,500
SUBTOTAL				$634,400
SUBTOTALS				**$748,808**
15% Management & Administration Contingency				$112,321
PROJECT TOTAL				**$861,129**

Table D-17
Site 13 Cluster IRA Quarterly Groundwater Monitoring - 8 Wells (5 new, 3 existing)
For Alternatives 3.A through 3.E

Item	Quantity	Unit Price	Unit	Extended Cost
Labor				
Engineering Technician (field)	4	$750	day	$3,000
Geologist - Jr Level (field)	1	$900	day	$900
Hydrogeologist - Senior Level	0.5	$1,100	day	$550
Project Manager	0.5	$1,300	day	$650
SUBTOTAL				$5,100
Equipment		Unit Price	Unit	Extended Cost
Field truck	2	$50	day	$100
Monitoring instruments	2	$100	day	$200
Phone	2	$5	day	$10
SUBTOTAL				$310
Materials		Unit Price	Unit	Extended Cost
Sampling Supplies	2	$100	LS	$200
Fed-Ex	4	$60	ea	$240
SUBTOTAL				$440
Subcontracts		Unit Price	Unit	Extended Cost
Analytical	9	$405	ea	$3,645
QUARTERLY SUBTOTAL				**$9,495**
15% Management & Administration Contingency				$1,424
PROJECT TOTAL				$10,919

Table D-18
Site 13 Cluster IRP Quarterly Groundwater Monitoring - 8 Wells (5 new, 3 existing)
For Alternative 5

Item	**Quantity**	**Unit Price**	**Unit**	**Extended Cost**
Labor				
Engineering Technician (field)	4	$750	day	$3,000
Geologist - Jr Level (field)	1	$900	day	$900
Hydrogeologist - Senior Level	0.5	$1,100	day	$550
Project Manager	0.5	$1,300	day	$650
SUBTOTAL				$5,100
Equipment		Unit Price	Unit	Extended Cost
Field truck	2	$50	day	$100
Monitoring instruments	2	$100	day	$200
Phone	2	$5	day	$10
SUBTOTAL				$310
Materials		Unit Price	Unit	Extended Cost
Sampling Supplies	2	$100	LS	$200
Fed-Ex	4	$60	ea	$240
SUBTOTAL				$440
Subcontracts		Unit Price	Unit	Extended Cost
Analytical (monitoring wells)	9	$405	ea	$3,645
Analytical (system)	21	$100	ea	$2,100
SUBTOTAL				$5,745
QUARTERLY SUBTOTAL				**$11,595**
15% Management & Administration Contingency				$1,739
PROJECT TOTAL				$13,334

Table D-19
Site 13 Cluster Quarterly Groundwater Monitoring Reporting
For Alternatives 3.A through 3.E

Item	**Quantity**	**Unit Price**	**Unit**	**Extended Cost**
Labor				
Engineering Technician	6	$560	day	$3,360
Geologist - Mid Level	4	$700	day	$2,800
AutoCAD/Graphics	1.5	$500	day	$750
Hydrogeologist - Senior Level	2	$1,100	day	$2,200
Project Manager	0.5	$1,300	day	$650
SUBTOTAL				$9,760
Equipment	Qty	Unit Price	Unit	Extended Cost
Computer Use	4	$5	day	$20
Materials	Qty	Unit Price	Unit	Extended Cost
Photocopies	500	$0.07	pg	$35
Fed-Ex	4	$15.0	ea	$60
SUBTOTAL				$95
SUBTOTALS				**$9,875**
15% Management & Administration Contingency				$1,481
PROJECT TOTAL				$11,356

Table D-20
Site 13 Cluster Present Worth Costing

Alternative 3.A: HRC-X

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$2,201,492			$330,224	$2,531,716	1	$2,531,716
1		$118,902		$17,835	$136,737	0.935	$127,792
2		$118,902		$17,835	$136,737	0.873	$119,432
3		$118,902	$1,228,414	$201,697	$1,546,345	0.816	$1,262,278
4		$118,902		$17,835	$136,737	0.763	$104,316
5		$118,902		$17,835	$136,737	0.713	$97,492
6		$118,902	$1,228,414	$201,697	$1,546,345	0.666	$1,030,395
7		$118,902		$17,835	$136,737	0.623	$85,153
8		$118,902		$17,835	$136,737	0.582	$79,582
9		$118,902	$499,224	$92,319	$707,776	0.544	$384,983
10		$118,902		$17,835	$136,737	0.508	$69,510
11		$118,902		$17,835	$136,737	0.475	$64,963
12		$118,902	$499,224	$92,319	$707,776	0.444	$314,261
13		$118,902		$17,835	$136,737	0.415	$56,741
14		$118,902		$17,835	$136,737	0.388	$53,029
15		$118,902	$499,224	$92,319	$707,776	0.362	$256,531
16		$118,902		$17,835	$136,737	0.339	$46,318
Total	$2,201,492	$1,902,432	$3,954,499	$1,202,360	$9,218,095		$6,664,201

Alternative 3.B: HRC-X and ORC

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,315,887			$197,383	$1,513,270	1	$1,513,270
1		$118,902		$17,835	$136,737	0.935	$127,792
2		$118,902	$226,389	$51,794	$397,085	0.873	$346,829
3		$118,902	$499,224	$92,319	$707,776	0.816	$577,756
4		$118,902	$226,389	$51,794	$397,085	0.763	$302,934
5		$118,902		$17,835	$136,737	0.713	$97,492
6		$118,902	$733,158	$127,409	$976,801	0.666	$650,883
7		$118,902		$17,835	$136,737	0.623	$85,153
8		$118,902		$17,835	$136,737	0.582	$79,582
9		$118,902	$499,224	$92,319	$707,776	0.544	$384,983
10		$118,902		$17,835	$136,737	0.508	$69,510
11		$118,902		$17,835	$136,737	0.475	$64,963
12		$118,902	$499,224	$92,319	$707,776	0.444	$314,261
13		$118,902		$17,835	$136,737	0.415	$56,741
14		$118,902		$17,835	$136,737	0.388	$53,029
15		$118,902	$499,224	$92,319	$707,776	0.362	$256,531
16		$118,902		$17,835	$136,737	0.339	$46,318
Total	$1,306,922	$1,902,432	$3,197,921	$956,033	$7,329,584		$5,021,935

Table D-20, continued
Site 13 Cluster Present Worth Costing

Alternative 3.C: iSOC

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,145,924			$171,889	$1,317,813	1	$1,317,813
1		$126,902	$28,938	$23,376	$179,215	0.935	$167,491
2		$126,902	$28,938	$23,376	$179,215	0.873	$156,534
3		$126,902	$28,938	$23,376	$179,215	0.816	$146,293
4		$126,902	$28,938	$23,376	$179,215	0.763	$136,723
5		$126,902	$28,938	$23,376	$179,215	0.713	$127,778
6		$126,902	$28,938	$23,376	$179,215	0.666	$119,419
7		$126,902	$13,688	$21,088	$161,678	0.623	$100,685
8		$126,902	$13,688	$21,088	$161,678	0.582	$94,098
9		$126,902	$13,688	$21,088	$161,678	0.544	$87,942
10		$126,902	$13,688	$21,088	$161,678	0.508	$82,189
11		$126,902	$13,688	$21,088	$161,678	0.475	$76,812
12		$126,902	$13,688	$21,088	$161,678	0.444	$71,787
13		$126,902	$13,688	$21,088	$161,678	0.415	$67,091
14		$126,902	$13,688	$21,088	$161,678	0.388	$62,701
15		$126,902	$13,688	$21,088	$161,678	0.362	$58,600
16		$126,902	$13,688	$21,088	$161,678	0.339	$54,766
Total	$1,145,924	$2,030,432	$310,500	$523,028	$4,009,884		$2,928,720

Alternative 3.D: Soybean Oil

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,018,689			$152,803	$1,171,492	1	$1,171,492
1		$118,902		$17,835	$136,737	0.935	$127,792
2		$118,902		$17,835	$136,737	0.873	$119,432
3		$118,902		$17,835	$136,737	0.816	$111,618
4		$118,902	$37,197	$23,415	$179,514	0.763	$136,950
5		$118,902		$17,835	$136,737	0.713	$97,492
6		$118,902		$17,835	$136,737	0.666	$91,114
7		$118,902		$17,835	$136,737	0.623	$85,153
8		$118,902	$18,599	$20,625	$158,126	0.582	$92,031
9		$118,902		$17,835	$136,737	0.544	$74,376
10		$118,902		$17,835	$136,737	0.508	$69,510
11		$118,902		$17,835	$136,737	0.475	$64,963
12		$118,902	$18,599	$20,625	$158,126	0.444	$70,210
13		$118,902		$17,835	$136,737	0.415	$56,741
14		$118,902		$17,835	$136,737	0.388	$53,029
15		$118,902		$17,835	$136,737	0.362	$49,560
16		$118,902	$18,599	$20,625	$158,126	0.339	$53,563
Total	$1,018,689	$1,902,432	$92,993	$452,117	$3,466,231		$2,525,025

Table D-20, continued
Site 13 Cluster Present Worth Costing

Alternative 3.E: iSOC and Soybean Oil

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,080,923			$162,138	$1,243,061	1	$1,243,061
1		$118,902	$5,719	$18,693	$143,314	0.935	$133,938
2		$118,902	$5,719	$18,693	$143,314	0.873	$125,176
3		$118,902	$5,719	$18,693	$143,314	0.816	$116,987
4		$118,902	$24,317	$21,483	$164,702	0.763	$125,651
5		$118,902	$5,719	$18,693	$143,314	0.713	$102,181
6		$118,902	$5,719	$18,693	$143,314	0.666	$95,496
7		$118,902	$5,719	$18,693	$143,314	0.623	$89,249
8		$118,902	$24,317	$21,483	$164,702	0.582	$95,858
9		$118,902	$5,719	$18,693	$143,314	0.544	$77,953
10		$118,902	$5,719	$18,693	$143,314	0.508	$72,854
11		$118,902	$5,719	$18.693	$143,314	0.475	$68,087
12		$118,902	$24,317	$21,483	$164,702	0.444	$73,130
13		$118,902	$5,719	$18,693	$143,314	0.415	$59,470
14		$118,902	$5,719	$18,693	$143,314	0.388	$55,580
15		$118,902	$5,719	$18,693	$143,314	0.362	$51,944
16		$118,902	$24,317	$21,483	$164,702	0.339	$55,790
Total	$1,080,923	$1,902,432	$165,894	$472,387	$3,621,636		$2,642,404

Alternative 4: In-Situ Chemical Oxidant

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,053,578			$158,037	$1,211,614	1	$1,211,614
1		$112,232	$292,896	$60,769	$465,897	0.935	$435,418
2		$112,232	$292,896	$60,769	$465,897	0.873	$406,932
3		$112,232	$292,896	$60,769	$465,897	0.816	$380,311
4		$112,232	$292,896	$60,769	$465,897	0.763	$355,430
5		$112,232	$292,896	$60,769	$465,897	0.713	$332,178
6		$112,232	$292,896	$60,769	$465,897	0.666	$310,447
7		$112,232	$266,129	$56,754	$435,115	0.623	$270,968
8		$112,232	$266,129	$56,754	$435,115	0.582	$253,241
9		$112,232	$266,129	$56,754	$435,115	0.544	$236,674
10		$112,232	$266,129	$56,754	$435,115	0.508	$221,190
11		$112,232	$266,129	$56,754	$435,115	0.475	$206,720
12		$112,232	$266,129	$56,754	$435,115	0.444	$193,196
13		$112,232	$266,129	$56,754	$435,115	0.415	$180,557
14		$112,232	$266,129	$56,754	$435,115	0.388	$168,745
15		$112,232	$266,129	$56,754	$435,115	0.362	$157,706
16		$112,232	$266,129	$56,754	$435,115	0.339	$147,389
Total	$1,053,578	$1,795,712	$4,418,663	$1,090,193	$8,358,146		$5,468,716

Table D-20, continued
Site 13 Cluster Present Worth Costing

Alternative 5: Ex Situ Groundwater Treatment

Year	Capital Costs	Annual O&M	Periodic Costs	15% Contingency	Total Cost Per Year	Discount Factor at 7%	Total Present Value Cost
0	$1,949,773			$292,466	$2,242,238	1	$2,242,238
1		$160,562	$75,600	$35,424	$271,587	0.935	$253,819
2		$160,562	$75,600	$35,424	$271,587	0.873	$237,214
3		$160,562	$75,600	$35,424	$271,587	0.816	$221,696
4		$160,562	$75,600	$35,424	$271,587	0.763	$207,192
5		$160,562	$75,600	$35,424	$271,587	0.713	$193,638
6		$160,562	$75,600	$35,424	$271,587	0.666	$180,970
7		$160,562	$52,001	$31,884	$244,448	0.623	$152,230
8		$160,562	$52,001	$31,884	$244,448	0.582	$142,271
9		$160,562	$52,001	$31,884	$244,448	0.544	$132,963
10		$160,562	$52,001	$31,884	$244,448	0.508	$124,265
11		$160,562	$52,001	$31,884	$244,448	0.475	$116,135
12		$160,562	$52,001	$31,884	$244,448	0.444	$108,538
13		$160,562	$52,001	$31,884	$244,448	0.415	$101,437
14		$160,562	$52,001	$31,884	$244,448	0.388	$94,801
15		$160,562	$52,001	$31,884	$244,448	0.362	$88,599
16		$160,562	$52,001	$31,884	$244,448	0.339	$82,803
Total	$1,949,773	$2,568,992	$973,615	$823,857	$6,316,237		$4,680,810

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D.1 BACKUP FOR ALTERNATIVE 3.A

Alternative #3 – In-Situ Bioremediation Treatment Duration

Watt Road location:
The aquifer cross section dimensions for Watt Road extraction barrier are assumed as follow: 150 foot length and 80 foot height. At an approximate averaged groundwater seepage velocity of 1.2 feet per day (ft/day), and an assumed porosity of 0.32, the following volume of ground would flow through this idealized cross section:

Cross sectional area of flow = 150 ft * 80 ft = 12,000 ft^2
Effective cross sectional area of flow = 12,000 ft^3 * 0.32 = 3,840 ft^2
Total water flow through cross section = 3,840 ft^3 * 1.2 ft/day = 4,608 ft^3/day
Gallons water flow through cross section = 4,608 ft^3/day * 7.48 gallons/ft^3 = 34,467 gallons/day

15 wells spaced at 10 feet intervals will form a barrier to intercept the plume migrating through the cross section.

Treatment duration calculation:
Modeling and aquifer parameters:
For the alluvial aquifer (beneath ABRES-A Lake), average K = 13 ft/day; for dune sand (paleochannel aquifer), average hydraulic conductivity, K = 45 ft/day;
uniform hydraulic gradient of 0.01;
average porosity of 0.32.

Based on these values, VOC travel is estimated as follows:
Estimated separation distance between source and Watt Road: 1,900 feet
Estimated separation distance between Watt Road and downgradient barrier (railroad): 1,590 feet

Groundwater velocity beneath Lake: 0.4 ft/day
Groundwater velocity beneath Watt Road and downgradient barrier: 1.2 ft/day

Travel time between source and Watt Road
= 1,900 ft / 0.4 ft/day = 4,750 days / 365 days/yr = 13 years.

Travel time between Watt road and west barrier
= 1,590 ft / 1.2 ft/day = 1,325 days / 365 days/yr = 3.6 years.

Therefore, a barrier at Watt Road must be maintained for 13 years after source area removal, which is assumed to be 3 years out. Total POP at Watt Road = 3 years source removal + 13 years source area transport = **16 years.** This represents a conservative scenario since degradation, dilution and dispersion will all serve to reduce VOC concentration over the course of their migration toward Watt Road.

We need only maintain the downgradient barrier for 3.6 years after clean up at Watt Road, which we will assume is 2.4 years out (EE/CA + installation + injection + time for dechlorination). Total POP at downgradient barrier = 2.4 years to cleanup Watt Road + 3.6 years down gradient transport = **6.0 years**

DRAFT - HRC-X Design Software for Barrier Treatment

US Version 1.0

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: VAFB Site 13 Cluster
Location: Downgradient Railroad location
Consultant: Tetra Tech

ite Conceptual Model/Extent of Plume Requiring Remediation

Length of Barrier (intersecting gw flow direction)	150	ft		
Depth to contaminated zone	100	ft		
Thickness of contaminated saturated zone	35	ft		
Aquifer soil type	sand			
Effective porosity	0.32			
Hydraulic conductivity	45	ft/day	1.6E-02	cm/sec
Hydraulic gradient	0.01	ft/ft		
Seepage velocity	513.3	ft/yr	1.406	ft/day

Dissolved Phase Electron Donor Demand	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoichiometry cont/H_2 (wt/wt)
Tetrachloroethene (PCE)	0.00	0.00	20.7
Trichloroethene (TCE)	0.00	0.00	21.9
cis-1,2-dichloroethene (DCE)	0.04	2.15	24.2
Vinyl Chloride (VC)	0.01	0.54	31.2
Carbon tetrachloride (CT)	0.00	0.00	19.2
Chloroform (CF)	0.00	0.00	19.9
1,1,1-Trichloroethane (TCA)	0.00	0.00	22.2
1,1-Dichlorochloroethane (DCA)	0.00	0.00	24.7
Hexavalent Chromium (Cr^{+6})	0.00	0.00	38.7
User added, also add stoichiometric demand	0.00	0.00	0.0
User added, also add stoichiometric demand	0.00	0.00	0.0

Competing Electron Acceptors:	CEA Conc (mg/L)	CEA Mass (lb)	Stoich. (wt/wt) e- acceptor/H_2
Oxygen Demand	2.38	128.02	8.0
Nitrate Demand	0.05	2.69	12.4
Bioavailable Manganese Demand	0.00	0.00	27.5
Bioavailable Iron Demand	7.00	376.53	55.9
fate Demand	82.00	4,410.79	12.0

crobial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x
Lifespan for one application	3	Year(s)

Injection Spacing and Dose:

Number of rows in barrier	1	rows
Spacing within rows	10	ft on center
Effective spacing perpendicular to flow (ft)	10.0	
Total number of HRC-X injection locations	15	points
Minimum required HRC-X application rate (lb/ft)	100.5	

(Dose amount is high. Please call Regenesis Tech Support to

Project Summary			
Number of HRC-X delivery points (adjust as necessary for site)		15	
HRC-X application rate in lbs/ft (adjust as necessary for site)		100.5	
Corresponding amount of HRC-X per point (lb)		3519	
Number of 30 lb HRC-X Buckets per injection point		117.3	
Total Number of 30 lb Buckets		1760	
Total Amt of HRC-X (lb)		52,800	
HRC-X Cost	$	7.50	
Total Material Cost	**$**	**396,000**	Cost is relatively high. Please call Regenesis to confirm.
Shipping and Tax Estimates in US Dollars			
Sales Tax rate: 8%	$	29,700	
Total Material Cost	$	425,700	
Shipping of HRC-X (call for amount)	$	-	
Total Regenesis Material Cost	**$**	**425,700**	

HRC-X Installation Cost Estimate (responsibility of customer to contract work)			**Other Project Costs**		
Length of each injection point (ft)		135	Design and Regulatory Issues	$	-
Total length for direct push for project (ft)		2,025	Groundwater monitoring and reporting	$	-
Estimated daily installation rate (ft per day: 300 for push, 150 for drilling)		300	Other	$	-
Estimated points per day (10 to 30 is typical for direct push)		2.2	Other	$	-
...ired number of days		7	Other	$	-
...cost for injection subcontractor	$	400	Other	$	-
...aily rate for injection subcontractor ($1-2K for push, $3-4K for drill rig)	$	1,500	Other	$	-
Total injection subcontrator cost for application	$	10,900	Other	$	-
Total Install Cost (not including consultant, lab, etc.)	**$**	**436,600**	**Total Project Cost**	**$**	**436,600**

DRAFT - HRC-X Design Software for Barrier Treatment

US Version 1.0

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: VAFB Site 13 Cluster
Location: Watt Road
Consultant: Tetra Tech

Site Conceptual Model/Extent of Plume Requiring Remediation

Length of Barrier (intersecting gw flow direction)	150	ft		
Depth to contaminated zone	100	ft		
Thickness of contaminated saturated zone	80	ft		
Aquifer soil type	sand			
Effective porosity	0.32			
Hydraulic conductivity	13	ft/day	4.6E-03	cm/sec
Hydraulic gradient	0.01	ft/ft		
Seepage velocity	148.3	ft/yr	0.406	ft/day

Dissolved Phase Electron Donor Demand	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoichiometry cont/H_2 (wt/wt)
Tetrachloroethene (PCE)	0.00	0.00	20.7
Trichloroethene (TCE)	0.00	0.00	21.9
cis-1,2-dichloroethene (DCE)	0.35	12.43	24.2
Vinyl Chloride (VC)	0.01	0.36	31.2
Carbon tetrachloride (CT)	0.00	0.00	19.2
Chloroform (CF)	0.00	0.00	19.9
1,1,1-Trichloroethane (TCA)	0.00	0.00	22.2
1,1-Dichlorochloroethane (DCA)	0.00	0.00	24.7
Hexavalent Chromium (Cr^{+6})	0.00	0.00	38.7
User added, also add stoichiometric demand	0.00	0.00	0.0
User added, also add stoichiometric demand	0.00	0.00	0.0

Competing Electron Acceptors:	CEA Conc (mg/L)	CEA Mass (lb)	Stoich. (wt/wt) e- acceptor/H_2
Oxygen Demand	2.38	84.53	8.0
Nitrate Demand	0.05	1.78	12.4
Bioavailable Manganese Demand	0.00	0.00	27.5
Bioavailable Iron Demand	7.00	248.63	55.9
Sulfate Demand	82.00	2,912.52	12.0

Microbial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x
Lifespan for one application	3	Year(s)

Injection Spacing and Dose:

Number of rows in barrier	1	rows
Spacing within rows	10	ft on center
Effective spacing perpendicular to flow (ft)	10.0	
Total number of HRC-X injection locations	15	points
Minimum required HRC-X application rate (lb/ft)	29.2	

(Dose amount is high. Please call Regenesis Tech Support to

Project Summary			
Number of HRC-X delivery points (adjust as necessary for site)		15	
HRC-X application rate in lbs/ft (adjust as necessary for site)		29.2	
Corresponding amount of HRC-X per point (lb)		2340	
Number of 30 lb HRC-X Buckets per injection point		78.0	
Total Number of 30 lb Buckets		1170	
Total Amt of HRC-X (lb)		35,100	
HRC-X Cost	$	7.75	
Total Material Cost	$	272,025	Cost is relatively high. Please call Regenesis to confirm.
Shipping and Tax Estimates in US Dollars			
Sales Tax rate: 8%	$	20,402	
Total Material Cost	$	292,427	
Shipping of HRC-X (call for amount)	$	-	
Total Regenesis Material Cost	$	292,427	

HRC-X Installation Cost Estimate (responsibility of customer to contract work)			**Other Project Costs**		
Length of each injection point (ft)		180	Design and Regulatory Issues	$	-
Total length for direct push for project (ft)		2,700	Groundwater monitoring and reporting	$	-
Estimated daily installation rate (ft per day; 300 for push, 150 for drilling)		300	Other	$	-
Estimated points per day (10 to 30 is typical for direct push)		1.7	Other	$	-
Required number of days		9	Other	$	-
Mob/demob cost for injection subcontractor	$	400	Other	$	-
Daily rate for injection subcontractor ($1-2K for push, $3-4K for drilling)	$	1,500	Other	$	-
Total injection subcontractor cost for application	$	13,900	Other	$	-
Total Install Cost (not including consultant, lab, etc.)	$	306,327	**Total Project Cost**	$	306,327

D.2 BACKUP FOR ALTERNATIVE 3.B

DRAFT - HRC-X Design Software for Barrier Treatment

US Version 1.0

Regenesis Technical Support, USA (949) 366-8000, www.regenesis.com

Site Name: VAFB Site 13 Cluster
Location: Downgradient Railroad location
Consultant: Tetra Tech

e Conceptual Model/Extent of Plume Requiring Remediation

Length of Barrier (intersecting gw flow direction)	150	ft		
Depth to contaminated zone	100	ft		
Thickness of contaminated saturated zone	35	ft		
Aquifer soil type	sand			
Effective porosity	0.32			
Hydraulic conductivity	45	ft/day	1.6E-02	cm/sec
Hydraulic gradient	0.01	ft/ft		
Seepage velocity	513.3	ft/yr	1.406	ft/day

Dissolved Phase Electron Donor Demand

	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoichiometry cont/H_2 (wt/wt)
Tetrachloroethene (PCE)	0.00	0.00	20.7
Trichloroethene (TCE)	0.00	0.00	21.9
cis-1,2-dichloroethene (DCE)	0.04	2.15	24.2
Vinyl Chloride (VC)	0.01	0.54	31.2
Carbon tetrachloride (CT)	0.00	0.00	19.2
Chloroform (CF)	0.00	0.00	19.9
1,1,1-Trichloroethane (TCA)	0.00	0.00	22.2
1,1-Dichlorochloroethane (DCA)	0.00	0.00	24.7
Hexavalent Chromium (Cr^{+6})	0.00	0.00	38.7
User added, also add stoichiometric demand	0.00	0.00	0.0
User added, also add stoichiometric demand	0.00	0.00	0.0

Competing Electron Acceptors:

	CEA Conc (mg/L)	CEA Mass (lb)	Stoich. (wt/wt) e acceptor/H_2
Oxygen Demand	2.38	128.02	8.0
Nitrate Demand	0.05	2.69	12.4
Bioavailable Manganese Demand	0.00	0.00	27.5
Bioavailable Iron Demand	7.00	376.53	55.9
Sulfate Demand	82.00	4,410.79	12.0

obial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x
Lifespan for one application	3	Year(s)

Injection Spacing and Dose:

Number of rows in barrier	1	rows
Spacing within rows	10	ft on center
Effective spacing perpendicular to flow (ft)	10.0	
Total number of HRC-X injection locations	15	points
Minimum required HRC-X application rate (lb/ft)	100.5	

(Dose amount is high. Please call Regenesis Tech Support)

Project Summary

Number of HRC-X delivery points (adjust as necessary for site)			15	
HRC-X application rate in lbs/ft (adjust as necessary for site)			100.5	
Corresponding amount of HRC-X per point (lb)			3519	
Number of 30 lb HRC-X Buckets per injection point			117.3	
Total Number of 30 lb Buckets			1760	
Total Amt of HRC-X (lb)			52,800	
HRC-X Cost		$	7.50	
Total Material Cost		**$**	**396,000**	Cost is relatively high. Please call Regenesis to confirm
Shipping and Tax Estimates in US Dollars				
Sales Tax	rate: 8%	$	29,700	
Total Material Cost		$	425,700	
Shipping of HRC-X (call for amount)		$	-	
Total Regenesis Material Cost		**$**	**425,700**	

HRC-X Installation Cost Estimate (responsibility of customer to contract work)			**Other Project Costs**	
Length of each injection point (ft)		135	Design and Regulatory Issues	$
Total length for direct push for project (ft)		2,025	Groundwater monitoring and reporting	$
Estimated daily installation rate (ft per day: 300 for push, 150 for drilling)		300	Other	$
Estimated points per day (10 to 30 is typical for direct push)		2.2	Other	$
Required number of days		7	Other	$
ation cost for injection subcontractor	$	400	Other	$
ate for injection subcontractor ($1.2K for push, $3.4K for drilling)	$	1,500	Other	$
otal injection subcontractor cost for application	$	10,900	Other	$
Total Install Cost (not including consultant labor, etc.)	$	436,600	Total Project Cost	$ 436,600

DRAFT - HRC-X Design Software for Barrier Treatment

US Version 1.0

Regenesis Technical Support: USA (949) 366-8000 www.regenesis.com

Site Name: VAFB Site 13 Cluster
Location: Wall Road
Consultant: Tetra Tech

Site Conceptual Model/Extent of Plume Requiring Remediation

Length of Barrier (intersecting gw flow direction)	150	ft		
Depth to contaminated zone	100	ft		
Thickness of contaminated saturated zone	80	ft		
Aquifer soil type	sand			
Effective porosity	0.32			
Hydraulic conductivity	13	ft/day	4.6E-03	cm/sec
Hydraulic gradient	0.01	ft/ft		
Seepage velocity	148.3	ft/yr	0.406	ft/day

Dissolved Phase Electron Donor Demand	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoichiometry cont/H_2 (wt/wt)
Tetrachloroethene (PCE)	0.00	0.00	20.7
Trichloroethene (TCE)	0.00	0.00	21.9
cis-1,2-dichloroethene (DCE)	0.35	12.43	24.2
Vinyl Chloride (VC)	0.01	0.36	31.2
Carbon tetrachloride (CT)	0.00	0.00	19.2
Chloroform (CF)	0.00	0.00	19.9
1,1,1-Trichloroethane (TCA)	0.00	0.00	22.2
1,1-Dichlorochloroethane (DCA)	0.00	0.00	24.7
Hexavalent Chromium (Cr^{6+})	0.00	0.00	38.7
User added, also add stoichiometric demand	0.00	0.00	0.0
User added, also add stoichiometric demand	0.00	0.00	0.0

Competing Electron Acceptors:	CEA Conc (mg/L)	CEA Mass (lb)	Stoich. (wt/wt) e- acceptor/H_2
Oxygen Demand	2.38	84.53	8.0
Nitrate Demand	0.05	1.78	12.4
Bioavailable Manganese Demand	0.00	0.00	27.5
Bioavailable Iron Demand	7.00	248.63	55.9
Sulfate Demand	82.00	2,912.52	12.0

Microbial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x
Lifespan for one application	3	Year(s)

Injection Spacing and Dose:

Number of rows in barrier	1	rows
Spacing within rows	10	ft on center
Effective spacing perpendicular to flow (ft)	10.0	
Total number of HRC-X injection locations	15	points
Minimum required HRC-X application rate (lb/ft)	29.2	

(Dose amount is high, Please call Regenesis Tech Support fo

Project Summary			
Number of HRC-X delivery points (adjust as necessary for site)		15	
HRC-X application rate in lbs/ft (adjust as necessary for site)		29.2	
Corresponding amount of HRC-X per point (lb)		2340	
Number of 30 lb HRC-X Buckets per injection point		78.0	
Total Number of 30 lb Buckets		1170	
Total Amt of HRC-X (lb)		35,100	
HRC-X Cost	$	7.75	
Total Material Cost	$	272,025	Cost is relatively high. Please call Regenesis to confirm
Shipping and Tax Estimates in US Dollars			
Sales Tax rate: 8%	$	20,402	
Total Material Cost	$	292,427	
Shipping of HRC-X (call for amount)	$	-	
Total Regenesis Material Cost	$	292,427	

HRC-X Installation Cost Estimate (responsibility of customer to contract work)			**Other Project Costs**		
Length of each injection point (ft)		180	Design and Regulatory Issues	$	-
Total length for direct push for project (ft)		2,700	Groundwater monitoring and reporting	$	-
Estimated daily installation rate (ft per day, 300 for push, 150 for drilling)		300	Other	$	-
Estimated points per day (10 to 30 is typical for direct push)		17	Other	$	-
Required number of days		9	Other	$	-
Mob/demob cost for injection subcontractor	$	400	Other	$	-
Daily rate for injection subcontractor ($1-2K for push, $3-4K for drilling)	$	1,500	Other	$	-
Total injection subcontractor cost for application	$	13,900	Other	$	-
Total Install Cost (not including consultant, lab, etc.)	$	306,327	**Total Project Cost**	$	306,[illegible]

REGENESIS ONLINE APPLICATION DESIGN SOFTWARE

OF Barriers - Slurry Injection | Load Defaults | Imperial (U.S.) Units

ORC DESIGN SOFTWARE FOR BARRIERS USING SLURRY INJECTION

Notes on Software Use:

- Use the **Tab** key or the mouse to move between fields. Note that the **Tab** key will move between all fields (including read-only output fields).
- Pressing **Enter** will submit the form, performing the same action as the "Save Calculator Results" at the bottom of the page. Note that posting data to the server may take time (especially on a slow connection); consider using **Tab** or the mouse to move between fields, rather than pressing **Enter**.
- "Saved" data in the Calculator only persists as long as this browser window remains open; note that there is a six hour inactivity timeout, after which all 'saved' calculator data is discarded. To permanently save your results, select "Save and Submit Calculator Results to Regenesis", which will email you a link from which you can later access your results at any time.
- The Software will not update calcuations until focus is removed from the field that is being edited (e.g. by selecting a new field, pressing **Tab**, or clicking elsewhere on the page) or when the calculator is saved by pressing **Enter**.
- Some printer-browser combinations have problems printing the results of the Software directly (via the File menu). You may need to select 'Print Preview' in your browser before selecting 'Print' (from within the 'Print Preview' interface).

Validation indicators:

= The data present in this field is valid.

= The entered data is invalid. It may be non-numeric, out of range, or is otherwise an unacceptable value for this field.

= One or more dependencies of this field are invalid. Check the form for invalid input fields.

= The validity of this field is unknown.

Site Conceptual Model / Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction):	150		
Depth to contaminated zone:	100		
Thickness of contaminated saturated zone:	35		
Nominal aquifer soil:	Sand		
Effective porosity:	0.32		
Hydraulic conductivity:	25	=	0.00881945
Hydraulic gradient:	0.01	/	
Seepage Velocity:	285.2	=	0.781

Dissolved Phase Oxygen Demand:

Individual species that represent oxygen demand:	Contaminant Conc (mg/L)	Contaminant Loading (/yr)	Stoich. (wt/wt) O_2/contam.	ORC () (10% O_2
Benzene	0.00	0.00	3.1	0
Toluene	0.00	0.00	3.1	0
Ethylbenzene	0.00	0.00	3.2	0
Xylenes	0.00	0.00	3.2	0
MTBE	0.00	0.00	2.7	0
Dichloroethene	0.04	1.20	0.7	8
Vinyl Chloride	0.01	0.30	1.3	4
User-Added (Please add Stoichometric Demand)	0.00	0.00	0.0	0
User-Added (Please add Stoichometric Demand)	0.00	0.00	0.0	0
Reduced metals: Fe (+2) and Mn(+2)	0.30	8.97	0.1	9
Measures of total oxygen demand:				
Total Petroleum Hydrocarbons	0.00	0.00	3.1	0
Biological Oxygen Demand (BOD)	0.00	0.00	1.00	0
Chemical Oxygen Demand (COD)	0.00	0.00	1.00	0

Length of time to evaluate contaminant flow into barrier: 3 yr

Summary of Estimated ORC Requirements:

	ORC For Dissolved Phase Flux ()	Add Dem Factor (1 to 10x)	ORC Total w/ Add Dem Factor	ORC Cost ()
Individual Species: Total BTEX, MTBE	64	5	318	3183
Total Petroleum Hydrocarbons	0	2	0	0
Biological Oxygen Demand (BOD)	0	2	0	0
Chemical Oxygen Demand	0	1	0	0

(COD)

Select above measure (radio button) to specify required ORC quantity (in inc nents): 330 **ORC**

Delivery Design for ORC Slurry

Spacing within rows ()	10.0	
Number of points per row	15	points/row
Number of rows	1.0	rows
Number of points in grid	15	points
Required ORC per	3.0	
Total ORC	1590	of ORC

Slurry Mixing Volume for Injections

Amount per location	105	
Bu per location	3.5	buckets
Design solids content (20-40% by wt. for injections)	30	%
Volume of water required per hole ()	30	
Total water for mixing all holes ()	445	
Simple ORC Backfilling: min hole dia. for 67% slurry	2.87	
Feasibility for slurry injection in sand	OK	
Feasibility for slurry injection in silt	OK	
Feasibility for slurry injection in clay	OK	

Project Summary

ORC bulk material for slurry injection ()	1575
Number of ORC containers	52.5
OR bulk material unit cost (per)	9.5
Total cost for ORC bulk material	14963

Shipping and Tax Estimates in U.S. Dollars

Sales Tax / Duty Rate (%)	7.50
Sales Tax ($)	1122.1875
Total material cost ($)	16084.6875
Shipping (Call for Rate)	0
Total Regenesis Material Cost ()	16084.6875

ORC Slurry Injection Cost Estimate
(Responsibility of Customer to Contract Work)

for each injection point (uncontaminated region thickness + HRC injection interval ())	135
Total length for direct push for project ()	2025
Estimated daily installation rate (per day; for push, for drilling)	400
Estimated points per day (15 to 30 is possible for direct push)	3.0
Required number of days	6
Mob/demob cost for injection subcontractor	1000
Daily rate for injection contractor ($1-2K for push; $3-4K for drill rig)	1500
Total injection subcontrator cost for application (not including consultant, lab, etc.) ()	10000

Other Project Cost Estimates

Design	0
Permitting and Reporting	0
Construction Management	0
Groundwater Monitoring and Reports	0
Other	0

Other	0
Other	0
Other	0
Total Project Cost ()	26084.6875

Save Calculator Results

Save and Submit Calculator Results to Regenesis

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D.3 BACKUP FOR ALTERNATIVE 3.C

inVentures Technologies Incorporated

Creating Value Through inNovation

www.isocinfo.com

iSOC™ SYSTEM QUOTATION

Quotation *Provided By:*	***Rep.***	Rey Rodriguez, $H_2O \cdot R^2$ Consulting Engineers, Inc. 2030 East Route 66, Suite 200 Glendora, CA 91740
	Tel	626 852-1235, 626 622-5090 Cell Phone
	Fax	626 852-1285
	Email	REYRH2OR2@AOL.COM

Customer (site owner): To be Provided
***Site Location/Name*:** To be Provided

Bill to:		***Ship To** (If Different that Billing Address):*	
Company	Tetra Tech, Inc.	Company	
Name	David Springer	Name	
Address	4213 State Street, Suite 100	Address	
City	Santa Barbara	City	
State	CA	State	
Zip Code	93110	Zip Code	
Tel:	(805) 681-3100	Tel:	
Fax	(805) 681-3108	Fax	
E-mail	david.springer@tetratech.com	E-mail	
Fed ID #		Fed ID #	
PO #		PO #	

Qty	***Description***	***Unit Price***	***Total***
2	iSOC Units (To Be Purchased)	US$ 3500.00	$7,000.00
	iSOC Units (To Be Rented for ______ months) First & Last month: $ ____________ Monthly Payments: $ ____________ Total rental amount: $:____________	US$ 300/mo.	
	3-iSOC Unit Control Panel (Purchase only)	US$ 1,250.00	
2	1-iSOC Unit Control Panel (Purchase only)	US$ 750.00	$1,500.00
	Other terms and conditions:		
	Shipping & Handling		$290.00
Total Due InVentures Technologies Incorporated			**$8,790.00**

Date of Quotation: April 15, 2004
Quotes Are Valid For 45-Days from Date of Quotation
***Anticipated Ship Date** (Please Allow 5-10 days): 4/16/04*

inVentures Payment And Rental Policy

Payment Terms: 30% on order. Balance net 30 days. All funds are in US$

Payment By Courier: Send to inVentures Technologies Incorporated (iTi), 670 Wilsey Road, Fredericton, NB, E3B 7K4, Att: J McCain, Telephone: 506-462-9080.

Payment Transfer: iTi Wire Transfer Account: 00884-003-4002077.

Special Notes:

- inVentures Technologies incorporated will invoice separately for iSOC equipment.
- The customer acknowledges and agrees to abide by the rental terms and conditions appended to this quotation, in the event that the customer wishes to rent the iSOCs.
- The iSOC Control Panels are available for purchase only.
- On the purchase order please provide Company name, Contact name, Shipping address, Phone and Fax and Purchase Order and Federal ID #.

iSOC™ Rental Policy:

- Rental rate for an iSOC™ unit is $300 per month payable to iTi
- Minimum six (6) month rental
- Customer may receive used, reconditioned or new equipment at the beginning of the rental period at the discretion of iTi
- At the end of six (6) months, the customer has the option to convert the rental to a purchase and apply one half (1/2) of the rental, being nine hundred dollars ($900) to the purchase price of $3500, thereby paying a balance of $2600 for each iSOC unit.
- In the event that the customer received used equipment at the beginning of the rental, iTi will replace the used iSOCs™ with new iSOCs™ at the customer's option if the customer pays the shipping and handling costs to return the used iSOCs™ to iTi and the shipping and handling costs for the new iSOCs™.
- In the event that the customer received new iSOCs™ at the beginning of the rental, there is no provision for new iSOCs™ if the customer chooses to convert the rental to purchase.
- Customer is responsible for return shipment of iSOCs to inVentures.

How To Order iSOC™ System Technology

Contact sales representative noted on this quotation (phone, fax or email).
Fax purchase order to the sales representative noted on this quotation.

www.isocinfo.com

D.4 BACKUP FOR ALTERNATIVE 3.D

ENVIRONMENTAL H2O

April 15, 2004

Andrea Resch
Tetra Tech Inc.
4213 State Street
Suite 100
Santa Barbara, CA 93105

RE: Preliminary Proposal for use of Soluble Remedial Substrate (SRS) Watt and RR Locations at a Confidential Site

Andrea:

Thank you for the opportunity to supply the following information on Emulsified Vegetable Oil application at above site.

Based on the information provided we have used the following assumptions in generation of the SRS requirements for the two areas:

	Watt	RR
Aquifer Parameters:		
Width of Plume:	150 feet	150 feet
Depth of groundwater:	80 feet	35 feet
Soil:	Silty Sand	Silty Sand
Total porosity:	0.38	0.38
Effective porosity:	0.323	0.323
Hydraulic conductivity:	3.4 ft/day	3.4 ft/day
Hydraulic Gradient:	0.01 ft/ft	0.01 ft/ft
Electron donor demand:		
VC	0.04 mg/L	0.04 mg/L
cis-1,2-DCE	0.44 mg/L	0.44 mg/L
Oxygen:	0.44 mg/L	0.44 mg/L
Nitrate:	0.0	0.0
Est. Mn demand:	0.4 mg/L	0.4 mg/L
Est Fe demand:	7.50 mg/L	7.50 mg/L
Est. sulfate reduction demand:	202 mg/L	202 mg/L

There will be 15 wells with a spacing of 10 feet.

Based on an application interval of 10 vertical feet, we estimate the following quantities of SRS will be necessary:

App. Time Interval (Yrs)	Area Name		SRS (lbs.)
3	Watt		1,637
3	RR		1,637
		Total	3,274

App. Time Interval (Yrs)	Area Name		SRS (lbs.)
5	Watt		2,424
5	RR		2,424
		Total	4,848

Costing:

3 yr. supply:	3,274 lbs @ $6.00/lb.	$19,644*
5 yr. supply:	4,848 lbs @ $5.50/lb.	$26,664*

w/ ~~8~~ 7.25% sales tax = $28,597

* The above prices do not include shipping or applicable tax.

NOTE: Injection of SRS via a series of permanent injection wells should be immediately followed by a clear water chaser. This will move SRS out of the well casing as well as flush it further into the aquifer. This is particularly appropriate for the Watt Area where DTGW is at about 80 feet bgs.

Thank you for the opportunity to provide this preliminary cost proposal for use of SRS. I would be pleased to discuss this further with you as necessary.

Best Regards,

Craig A. Sandefur
Environmental H_2O

D.5 BACKUP FOR ALTERNATIVE 4

Alternative #4 – Chemical Oxidation calculation

Watt Road location:
Targeted aquifer dimensions for Watt Road extraction barrier are assumed as follow:
150 foot length; 80 foot height; and 10 foot thickness. At an approximate averaged groundwater seepage velocity of 1.2 feet per day (ft/day), and an assumed porosity of 0.32, the following volume of ground would flow through this idealized cross section:

Cross sectional area of flow = 150 ft * 80 ft = 12,000 ft^2
Effective cross sectional area of flow = 12,000 ft^3 * 0.32 = 3,840 ft^2
Total water flow through cross section = 3,840 ft^2 * 1.2 ft/day * 7.48 gallons/ft^3 =34,467gallons/day (gpd)

With a low natural organic carbon content in the dune sands and a dissolved phase VOC plume, it is estimated that $KMnO_4$ would persist in the aquifer for 120 days following injection. Subsequent injection would be completed at 120 day intervals to replenish the consumed oxidant. This assumption would be subject to verification by completing a simple bench scale oxidant demand study. Using this assumption:

120 days * 34,467 gpd = 4,136,040 gallons of water, or 15,707,335 liters of water would require treatment. This incoming groundwater is assumed to have a concentration of total DCE of 350 µg/L, and vinyl chloride of 10 µg/L.

Total mass of DCE (from 2004 monitoring dart) is calculated as 15,707,335 * 350 µg/L * (1gram/10^{-6} µg) = 5,501 grams, or 5.5 kg DCE.

Total mass of VC is calculated as 15,707,335 * 10µg/L * (1gram/10^{-6} µg) = 157 grams, or 0.16 kg

Using an average weighted ratio of $KMnO_4$ mass to DCE mass of 2.6:1 and to VC mass of 8.0; the minimum mass of solid $KMnO_4$ mass is calculated as [(2.6 * 5.5) + (8.0*0.16)] = 15.58 kg. To account for competing reaction with other groundwater constituents and soil matrix effects (i.e. the high organic peat layers in deep aquifer sediments at Watt Road), a ratio of 15:1 is applied, yielding a total estimate pure $KMnO_4$ mass of 15.58 * 15 = 233.7 kg, or approximately 515.3 pounds.

Since $KMnO_4$ is available in a 2% powder form in groundwater, 515.3 pounds / 0.02 = 25,765 pounds would be injected every 120 days.

Down gradient Railroad location
The total mass of DCE at this location (from 2004 monitoring data) is calculated as 15,707,335 liters * 40 * (1gram/10^{-6} µg) = 628 grams, or 0.63 kg of DCE.

Total mass of VC is calculated as 15,707,335 * 2µg/L * (1gram/10^{-6} µg) =31.4 grams, or 0.03 kg.

Using an average weighted ratio of $KMnO_4$ mass to DCE mass of 2.6:1 and to VC mass of 8.0; the minimum mass of solid $KMnO_4$ mass is calculated as [(2.6 *0.63) + (8.0*0.03)] = 1.88 kg.
To account for competing reaction with other groundwater constituents and the soil matrix, a 15:1 ratio is applied, yielding a total estimate pure $KMnO_4$ mass of 1.72 * 15 = 25.8 kg, or approximately 57 pounds. Since $KMnO_4$ is available in a 2% powder form in groundwater, 57 pounds / 0.02 = 2,850 pounds would be injected every 120 days.

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D.6 BACKUP FOR ALTERNATIVE 5

Alternative #5 – GW Extraction Calculation

Watt Road location:
The aquifer cross section dimensions for Watt Road extraction barrier are assumed as follow: 150 foot length and 80 foot height. At an approximate averaged groundwater seepage velocity of 1.2 feet per day (ft/day), and an assumed porosity of 0.32, the following volume of ground would flow through this idealized cross section:

Cross sectional area of flow = 150 ft * 80 ft = 12,000 ft^2
Effective cross sectional area of flow = 12,000 ft^3 * 0.32 = 3,840 ft^2
Total water flow through cross section = 3,840 ft^3 * 1.2 ft/day = 4,608 ft^3/day
Gallons water flow through cross section = 4,608 ft^3/day * 7.48 gallons/ft^3 = 34,467 gallons/day

8 wells are required to intercept the plume migrating through the cross section. We estimate the radius of influence of 12 feet per well with partial overlapping between extraction well radii.

Required pumping rates in gallons per minute (gpm) per well are estimated as follow:
34,467 gpd / 8 wells = 4,558 gpd / well * 1day /24 hr * 1 hr / 60 min = 2.8 gpm per well

Treatment duration calculation:
Modeling and aquifer parameters:
For the alluvial aquifer (beneath ABRES-A Lake), average K = 13 ft/day; for dune sand (paleochannel aquifer), average hydraulic conductivity, K = 45 ft/day;
uniform hydraulic gradient of 0.01;
average porosity of 0.32.

Based on these values, VOC travel is estimated as follows:
Estimated separation distance between source and Watt Road: 1,900 feet
Estimated separation distance between Watt Road and downgradient barrier (railroad): 1,590 feet

Groundwater velocity beneath Lake: 0.4 ft/day
Groundwater velocity beneath Watt Road and downgradient barrier: 1.2 ft/day

Travel time between source and Watt Road
= 1,900 ft / 0.4 ft/day = 4,750 days / 365 days/yr = 13 years.

Travel time between Watt road and west barrier
= 1,590 ft / 1.2 ft/day = 1,325 days / 365 days/yr = 3.6 years.

Therefore, a barrier at Watt Road must be maintained for 13 years after source area removal, which is assumed to be 3 years out. Total POP at Watt Road = 3 years source removal + 13 years source area transport = **16 years.** This represents a conservative scenario since degradation, dilution and dispersion will all serve to reduce VOC concentration over the course of their migration toward Watt Road.

We need only maintain the downgradient barrier for 3.6 years after clean up at Watt Road, which we will assume is 2.4 years out (EE/CA + installation + injection + time for dechlorination). Total POP at downgradient barrier = 2.4 years to cleanup Watt Road + 3.6 years down gradient transport = **6.0 years**

E EVALUATION OF TEMPORARY RISKS AND POTENTIAL IMPACTS

E.1 EVALUATION OF TEMPORARY RISKS AND POTENTIAL IMPACTS

The forthcoming Site 13C IRA Work Plan will outline all field activities including drilling actions, addition of groundwater amendments to facilitate in-situ bioremediation, and O&M activities. The installation of the injection and monitoring well array will require approximately 2-3 months and O&M will continue throughout the period of performance, as determined by the Air Force.

E.1 Worker Health and Safety Plan

Appendix B is a Health and Safety Plan developed to protect workers during implementation of the IRA. The plan describes general site conditions and addresses potential hazards posed by chemicals in the environment, waste materials, and by working near heavy equipment. Subcontractors engaged in removal activities will follow the requirements of the Plan and sign the accompanying Health and Safety Plan Consent Sheet(s).

E.2 Environmental Protection Plan

The environmental protection plan described in this EE/CA will be implemented during field activities to minimize short-term effects on surrounding environmental conditions. Components of the environmental protection plan described below include:

- Earth;
- Air;
- Surface water and groundwater;
- Plant life;
- Animal life;
- Land use;
- Natural resources;
- Risk of upset;
- Transportation/circulation;
- Public services;
- Energy;
- Utilities;
- Noise;
- Public health and safety;

- Aesthetics;
- Cultural/paleontological resources;
- Cumulative effects;
- Population;
- Housing; and
- Recreation.

These components have been recognized in California Environmental Quality Act (CEQA) as environmental concerns that should be addressed prior to any project that has the potential to affect them. The following discussion describes environmental concerns and mitigation, if necessary, for the IRA at Site 13C.

Earth

Installation of injection wells and monitoring wells and injection of amendments to the groundwater would have short-term impacts on soils during implantation of the IRA. Drill rigs, injection equipment, and earthmoving equipment used during remedial activities may affect surface soils. During O&M activities, minimal effects to surface soils will occur when driving vehicles to each well location. Equipment operation and travel will be limited to only what is necessary to complete the removal action to minimize impacts to onsite native soils.

Air

Vehicular traffic into and out of Site 13C will be on asphalt and/or concrete. Due to drilling locations located in sand dunes at both sites, vehicle traffic may cause dust to get into the air. Dust control measures (such as application of water) will be used if dust is generated.

Surface and Ground Water

The IRA will not disturb surface water at Site 13 C. Groundwater will be injected with an amendment and subsequently monitored during the IRA. This activity will help to eliminate groundwater contamination resulting in a future beneficial effect.

Plant Life

No effects to vegetation are anticipated during the removal action at Site 13C. Drill rigs, injection equipment, and earthmoving equipment used during IRA implementation would avoid vegetation where possible. Equipment operation and travel will be limited to only what is necessary to complete the removal action to avoid impacts to onsite vegetation.

Animal Life

The IRA at Site 13C would not significantly affect animal life. Short-term construction would occur at the site during the removal action and may temporarily affect localized habitat use due to noise disturbance. Fieldwork for the Site 13 IRA will be scheduled to accommodate for snowy plover nesting season.

Land Use

The IRA at Site 13C would not alter the present or planned land use at this site.

Natural Resources

No effects on natural resources are anticipated during the IRA at Site 13C. The proposed IRA would not result in an increased rate of use of natural resources, nor would it result in any substantial depletion of nonrenewable resources

Risk of Upset

No risk of upset is posed from the removal action at Site 13C. The IRA would not increase risk of an explosion or the release of hazardous substances in the event of an accident or upset conditions. The removal action would not interfere with community response plans or public emergency evacuation plans.

Transportation/Circulation

Minimal short-term transportation impacts would result from the IRA at Site 13C. Once the investigation derived waste (IDW) is analyzed it will be removed from the site for proper disposal. It is estimated that 14 truckloads of soil generated from drilling activities will be hauled away from Site 13C. Licensed waste haulers will transport contaminated sediments and all California Department of Transportation requirements will be adhered to.

Public Services

There would be no effects on public service needs due to the IRA at Site 13C. No additional police protection would be required. Possible fire hazards, such as vehicle sparks igniting brush or vegetation, will be mitigated by requiring contractors to park in designated areas and by equipping the removal action team with fire fighting equipment, such as fire extinguishers, and shovels.

Energy

No effects on energy requirements (such as substantial increase in demand upon existing sources of energy or a requirement of the development of new sources of energy) would result from the IRA.

Utilities

No effects on utilities would occur from the IRA at Site 13C. Prior to excavation, a *Base Civil Engineer Work Request, 30 SW Form 35* would be obtained. This permit requires the notification and approval of the base utilities shops and 30 Communications Squadron. Upon notification, these divisions will flag the location of utilities such as telephone, fiber-optic, and electric lines in the project area.

Noise

Some short-term noise impacts to workers will occur from the operation of machinery and trucks. Wearing proper personal protective equipment (i.e., earplugs or other hearing protection), as discussed in the Site-Specific Health and Safety Plan (Appendix B), will mitigate these impacts Although the removal action will temporarily raise ambient noise levels in the project area, there are no known sensitive noise receptors in the project vicinity Occupational Safety and Health Administration regulations limiting noise exposure in the workplace will be followed to reduce impacts in the project area.

Public Health and Safety

No short-term impacts to public health and safety would occur during the IRA at Site 13C Overall beneficial effects to public health and safety would result from implementing in-situ bioremediation Public health may be affected during the transportation of the IDW if an accident were to occur. In the event of an accident, truck drivers will isolate the area of a spill and call proper authorities.

Aesthetics

Short-term aesthetic impacts would occur during the IRA at Site 13C from the sight of construction equipment. The only foreseen long term aesthetics effects would be the yellow well monuments and bollards to be installed at each injection and monitoring well.

Cultural/Paleontological Resources

The IRA at Site 13C is not anticipated to disturb cultural or paleontological resources. However, prior to excavation, a *Base Civil Engineer Work Request, 30 SW Form 35* would be obtained. Approval would be obtained from 30 CES/CEVPC (Cultural Resources) prior to drilling. If required, an archeological monitor will be on site during the IRA.

Cumulative Effects

Cumulative impacts to traffic, noise, and air quality would occur if the IRA were to coincide with other nearby construction projects. No other construction activities are currently known to occur at the same time as the IRA, therefore there would be no expected cumulative effects.

Population

The IRA at Site 13C would have no effect on the location, distribution, density, or growth rate of the local population.

Housing

The IRA at Site 13C would not affect local housing needs.

Recreation

The IRA at Site 13C would have no effects on the quality or quantity of local recreation uses. Site 13C is not open to the public and is not used for recreation.

F RESPONSES TO STATE REGULATORY AGENCY COMMENTS

RESPONSES TO COMMENTS from the Regional Water Quality Control Board – Central Coast Region dated 11 January 2005 on the Draft Site 13 Cluster Engineering Evaluation/Cost Analysis

General Comment 1: Schedule
Based on the schedule shown in Table 5-1, the Draft Interim Removal Action (IRA) Work Plan will be included in the Final EE/CA We cannot approve a decision document as final if it includes material that we have not previously reviewed and accepted. We suggest that the Air Force revise the schedule to allow for regulatory review and approval of the work plan prior to inclusion in the Final EE/CA. Alternatively, the IRA Work Plan could be submitted as a stand-alone document and not included in the EE/CA.

Air Force Response:
The Air Force will revise the Schedule to provide for regulatory review/approval of the IRA Work Plan prior to inclusion in the Final EE/CA.

General Comment 2: Remedial Design
The discussion of alternatives contains some very specific design elements, such as injection well spacing and quantity of substrate. We understand that it is necessary to make such assumptions to compare the alternatives. However, the text should qualify these assumptions and indicate that the details of the remedial design and supporting information (e g , technical basis for well spacing) will be presented in the work plan.

Air Force Response:
The text in section 4.5.1 Screening of in-situ Bioremediation Alternatives, will be revised to state that design specifics including substrate quantities and well spacing details will be addressed in the IRA work plan, and are discussed in the subsequent sections to provide for a uniform basis for alternatives comparison.

General Comment 3: Appendix B, Applicable, Relevant and Appropriate Requirements (ARARs)
We suggest that the Air Force designate one document (e g., Management Action Plan) as the general reference for facility-wide ARARs. The discussion of ARARs in site documents could then be limited to site or action-specific ARARs, which should also be discussed in the text of the site document. This approach would expedite document review and ensure that all appropriate agencies have an opportunity to review the ARARs. Please note that ARARs in Appendix E of the current Management Action Plan (Final Revision 9, August 2004) need to be expanded as discussed in our October 21, 2004 State (Regional Board and DTSC) letter. Also see Specific Comment 3.

Air Force Response:
Comment noted. The MAP is the appropriate source document for facility wide ARARs. It is our understanding that the MAP will be appropriately updated in 2005. The revised ARARs listed in the Draft 13C EE/CA are limited to chemical, location, and action specific ARARs.

Specific Comment 1: Section 4.5.1.2, Alternative 3.B: Addition of HRC-X and ORC
It appears that the word "leach" in the 6th sentence of the last paragraph should be "lead."

Air Force Response:
Comment noted. The word leach will be changed to "lead", as was intended.

Specific Comment 2: Section 5.2, Preliminary Schedule and Table 5-1

Please revise the schedule to address General Comment 1 and revise the dates shown in Table 5-1 to reflect the current status of the project.

Air Force Response:

The Air Force will add a statement in Section 5.2 indicating that regulators will be provided an opportunity to review and approve the Draft IRA Work Plan prior to its inclusion in the Final EE/CA. Table 5-1 will be revised to reflect this issue and will be updated accordingly.

Specific Comment 3: Appendix B, Applicable, Relevant and Appropriate Requirements

The ARARs in Appendix B are generally consistent with current Regional Board ARARs Please make the following edits to the items as numbered in Appendix B

Please expand the discussion under Comments as follows: "The Basin Plan for RWQCB CCR assigns the beneficial use of drinking water to all groundwater in the region (with the exception of the Soda Lake sub-basin). The Basin Plan supersedes Resolution 88-63, therefore, the beneficial use of drinking water must be protected regardless of the Resolution's criteria."

Please correct "Discharge' as the beginning of the second sentence under "Description."

Please delete this item since it redundant with Item 9.

All appropriate agencies that did not receive the EE/CA (e.g., U.S. Department of Fish and Game and Santa Barbara County) should also have an opportunity to review and comment on the ARARs.

Air Force Response:

9) The discussion will be expanded to include the language provided for the "Basin Plan" ARAR.

10) Discharge will be replaced with "discharges".

11) The second entry of Resolution 88-63 will be deleted as suggested, due to its redundancy. The Draft Final EE/CA will be made available for public review, including but not limited to, review by the California Department of Fish and Game, and Santa Barbara County.

Draft Groundwater Treatability Study Report

General Comment 1: Evaluation of Test Results

The Treatability Study meets the objective of demonstrating that HRC-X can create conditions conducive to complete dechlorination of contaminants of concern (COC). The presence of ethene in conjunction with a significant decrease in the concentration of cis-dichloroethene (cis-DCE) in the nearest downgradient well (14-MW-3) indicates that complete dechlorination is occurring. The high volatility of cis-DCE's breakdown products (vinyl chloride, ethene, and ethane) probably accounts for the lack of a stoichiometric balance between parent and daughter products. We suggest that the Air Force evaluate the study results further and determine if the data can be used to optimize subsequent remedial actions. For example, what can we conclude about travel time, radius of influence, and required pore volumes of injectate?

Air Force Response:

The Air Force concurs with RWQCB's interpretation that the treatability study has met its original objectives. The text below expands on the findings of the treatability study, and addresses radius of influence, travel time, and injectate volumes In accordance with RWQCB General Comment 2, these issues are best addressed in the IRA Work Plan. The Air Force will include the write up below in the Draft IRA Work Plan under a section entitled "Basis for Design".

Tetra Tech recently completed a treatability study in the Watt Road embankment area, which was initiated in fall 2003. Monitoring data spanning 12 months following injection is summarized in Appendix A of this IRA Work Plan. The objective of the study was to provide sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analyses, to support remedial design of a selected alternative, and reduce the cost and performance uncertainties for treatment alternatives to acceptable levels so that a final remedy can be selected. The treatability study assessed the ability of Hydrogen Release Compound, Extended Release Formula (HRC-X) and Primer, products manufactured by Regenesis, to enhance already semi-anaerobic conditions within a portion of the aquifer at Watt Road, and anaerobically degrade 1,1-DCE, *trans*-1,2-DCE, *cis*-1,2-DCE, and vinyl chloride from groundwater near wells 14-MW-3, 14-MW-9, and 14-MW-10. The area selected for the treatability study is characterized by naturally moderately reducing conditions and contains DCE isomers and vinyl chloride at concentrations ranging from tens to hundreds of micrograms per liter.

On 11 through 12 November 2003, diluted HRC-X and undiluted Primer were injected into six injection wells (wells 14-INJ-1 through 14-INJ-6) positioned upgradient from three treatability study monitoring wells in the paleochannel at Site 13 Cluster (Figure 1). Injection wells were installed as nested well pairs, spaced at 10 foot intervals. Each of the three nested injection wells includes a screened interval within the upper aquifer and a separate screened interval within the lower aquifer. Following substrate injection, heated water was injected into each well to expand the radius of injection and clear the injection wells. The addition of Primer was designed to promote rapid dilution and dispersion of electron donor to quickly create anaerobic aquifer conditions in the targeted treatment zone. The viscous, low solubility HRC-X was designed to remain relatively immobile within the vicinity of the injection wells, and sustain the anaerobic conditions created by the Primer through slowly releasing hydrogen. The high relative groundwater velocity (estimated as 1.2 feet/day) is relied upon to dilute, disperse, and ultimately transport the injectate towards the downgradient monitoring wells

Four monitoring wells were used to evaluate the effectiveness of the treatability study (Figure A-1 of Appendix A). These wells include:

- upgradient existing well 14-MW-2, screened in the deeper zone, located near the western edge of ABRES-A Lake, 440 feet upgradient of the injection well line;
- existing monitoring well 14-MW-3, screened in the deeper zone, located 10 feet downgradient of the injection well line;
- new well 14-MW-9, screened in the shallow zone, 25 feet downgradient; and
- new well 14-MW-10, screened in the deeper zone, located 35 feet downgradient of the injection line.

Results for the first twelve months of monitoring are provided in Appendix A of this IRA Work Plan. Monitoring data indicate that subsurface aquifer conditions within the treatment zone have been appropriately changed to strongly reducing, with a resultant decline in targeted constituent concentrations (primarily *cis*-1,2-DCE) completely through the ethane (the end product of sequential dechlorination of the parent compound DCE), without an increase of intermediate daughter product vinyl chloride above historically measured levels (Table A-1 and Figures A-2 through A-8 of Appendix A). Detectable metabolic acids in monitoring wells indicate breakdown of HRC-X and Primer in the treatment zone (Table A-2 of Appendix A). This process provides the hydrogen ions necessary for microbes to degrade chlorinated solvents present in the zone of influence. In addition, various water quality parameters (i.e. dissolved oxygen, oxidation-reduction potential, methane, sulfide, etc.) support an interpretation of enhanced reducing conditions (Table A-3 of Appendix A). The injection zone and associated wells continue to be monitored quarterly under the BGMP.

Evaluation of the groundwater monitoring data from treatment zone monitoring wells associated with the Watt Road HRC-X injection treatability study yields some important findings as they relate to radius of influence and injectate travel time issues associated with the proposed Watt Road embankment IRA implementation. Specifically, the monitoring data were evaluated for:

- changes in *cis*-1,2-DCE concentrations, and production of degradation by products vinyl chloride and ethane;
- increases in TOC and presence of metabolic acids signifying presence and breakdown of the injected substrate; and
- presence of indicator parameters supporting interpretation of anaerobic conditions including low DO and ORP values, detectable methane, sulfide and Fe^{2+}, and reductions in concentrations of alternate electron acceptors (sulfate and nitrate).

Radius of Influence

As a first order approximation, the total volume of injected fluids (664 gallons) is estimated to comprise less than 10% of the total volume of the aquifer extending a radial distance of 10 feet around each of the three injection wells. Therefore, from a standpoint of total fluid displacement, an insufficient volume of injectate was added to completely displace the groundwater residing in the treatment zone between the injection wells and the monitoring wells. A specific chemical tracer was not added to the injectate used in the treatability study, therefore the effects of substrate injection at distance from the injection wells must be assessed by evaluating geochemical changes in the parameters listed in the above bullets. The most appropriate geochemical "tracers" to use in this case are total organic carbon and metabolic acids, which are a direct result of substrate presence and substrate breakdown, respectively. Due to the relatively high cost of installing monitoring wells at Site 13C, monitoring data is limited to one upgradient well and three downgradient wells.

Monitoring wells constructed within the deeper aquifer (14-MW-3 and 14-MW-10) each indicated increases of TOC above background within 2 months following injection, indicating the arrival of injection fluid. TOC for well 14-MW-9 did not rise significantly over its baseline value (Table A-3). The presence of metabolic acids is most pronounced for well 14-MW-10 after 2 months where acetic, lactic and propionic acids were present at concentrations of 47, 73, and 55 mg/l, respectively (Table A-2) Wells 14-MW-3 and 14-MW-9 indicated lower values of metabolic acids, primarily acetic acid, after 6 months time. Collectively, the available data confirm that the injection fluids and/or breakdown products from the injection fluids have reached the monitoring wells spaced from 10 to 35 feet downgradient from the injection well array. Changes are most pronounced in the deeper zone wells where the VOC concentrations are also greatest (Table A-1).

Following the initial injection activity, the substrate begins to break down and move downgradient (west) in the aquifer in response to the regional gradient. During this downgradient movement, dispersion occurs which effectively expands the radius of influence of the injection well array in the downgradient direction. Guidance documents indicate that appropriate well spacing for permeable formations to be 10 to 15 feet for "viscous fluid systems", and 20 to 30 feet for larger volume soluble substrate systems (AFCEE 2004). Based on review of the limited existing monitoring data, there is no evidence of lateral gaps in the treatment zone For a larger scale injection barrier, the existing well spacing of 10 feet (ROI of 5 feet) is proposed to be expanded to a well spacing of 20 feet, with a contingency for additional injection wells to be added at a later date, based on evaluation of process monitoring data.

Travel Time

To assess the travel times of the injectate, measured as the duration between first injection and first detection at a monitoring well, the MNA parameters available from the three monitoring wells were evaluated with respect to significant changes above background (i.e. accounting for changes in upgradient well 14-MW-2) following injection. Data are available at monitoring events at 10 days following injection, at 1 month, 2 months, 3 months, and quarterly thereafter for 9 months (Table A-3). Where significant changes were observed in laboratory data, the monitoring event following injection, in days, was used to estimate travel time, and the travel time was divided by the separation distance between the monitoring well exhibiting the changes from the injection well array (in feet), to arrive at an estimated rate of travel in feet per day.

Referring to well 14-MW-3, positioned 10 feet from the injection wells, TOC shows a significant change compared to background (14-MW-2, which showed essentially no change over 9 months) during the 1 month event. It is possible that the soluble Primer may have moved past well 14-MW-3 between the 10-day and 1 month events. This yields a calculated time of 30 days to travel a 10 foot distance (0.3 feet per day), and perhaps a bit faster. Metabolic acids are not detected at month 1 for well 14-MW-3 (Table A-2). A second arrival front appears at the 6 month interval in the data. This is interpreted to represent the arrival of the slower moving HRC-X. Showing significant changes at 6 months are increases in methane and ethene, total sulfide, and alkalinity, with declines in sulfate over background (Table A-3). These parameters are consistent with the arrival of a reducing front, interpreted to correspond to the travel time for the HRC-X to reach monitoring well 14-MW-3. Travel time of HRC-X is estimated at 6 months over 10 feet (0.06 feet/day).

Referring to well 14-MW-10, the most marked change is seen for increases in TOC, alkalinity, and sulfide, as well as metabolic acids, all consistent with arrival of the injectate, after 2 months compared to background (Tables A-2 and A-3). Also, methyl ethyl ketone (MEK) is first observed during the 2 month event, suggesting a fermentation process, typically associated with stronger (i.e. faster acting Primer) reactions (Table A-1). MEK was also detected in months 3, 6, and 9, but has declined to below detection limits in the 12 month event. Therefore a travel time of 60 days is used, with a separation distance of 35 feet from the injection array, to yield an estimated rate of travel rate of 0.58 feet/day for well 14-MW-10. This rapid movement is attributed to arrival of the high solubility Primer. A second migration front is appearing in the MNA dataset at 9 months (Table A-3). This slower front is characterized by lower concentration but detectable metabolic acids, declining MEK concentrations, and increasing sulfide and methane over background (see Appendix A).

Substrate Mass Calculation

An estimate of substrate mass to be injected into the expanded treatment zone was calculated using basic hydrogen demand calculations from site groundwater data, with a targeted treatment duration addressing a specified area of the Watt Road groundwater aquifer. Parameter inputs and assumptions, and the total calculated mass are summarized in Table 1 (which will be included as Table 2.3-1 in the IRA Work Plan).

Specific Comment 1: Methods
The first sentence of the fourth paragraph, which begins "Following installation," is incomplete. Please state what activity was conducted in accordance with the work plan.

Air Force Response:
The Air Force will add the word "developed" to the sentence.

Specific Comment 2: Results and Table 3

The text discusses changes in COC concentrations as percent change from a single baseline-sampling event. There are problems with using this type of analysis to determine concentration trends. For example, Table 3 reports a 97 percent decrease in trichlorethene (TCE) in the background well 14-MW-2. Based on historical data for this well, this magnitude of change is consistent with normal fluctuations. Table 3 also calculates that a change in TCE concentration from 1.24 to <0.2 microgram/liter represent a 78 percent decrease. However, this magnitude of change could also be the result of normal fluctuations. Please consider evaluating concentration trends according to one of the statistical approaches included in: *Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents*, Air Force Center for Environmental Excellence, August 2004 (http://www.afcee.brooks.af.mil/products/techtrans/bioremediation/downloads/PrinciplesandPractices.pdf).

Air Force Response:

The Air Force will delete the "percent change" column from the data tables, as this presentation can be misleading in instances of reporting percentage changes in low constituent concentrations. The treatability study graphic representations of monitoring data, which present contaminant concentrations in terms of molar equivalents, were prepared based on review of AFCEE guidance. These graphics effectively convey concentration trends during the treatability study.

Specific Comment 3: Results

Please include a discussion of the occurrence of ketones and aldehydes, which can be by-products of reductive dechlorination. Table 4 shows that several of these compounds were detected in groundwater.

Air Force Response:

The Air Force will include the following text in Section 2.3.1.1 under the heading *Metabolic Byproduct VOCs* in the treatability study write up in the IRA Work Plan.

Various ketones including acetone, 2-butanone (MEK), 2-hexanone, and 4-methyl-2-pentanone were detected, as well as carbon disulfide; in monitoring wells during the treatability study (Table 4 of Attachment A). The presence of these constituents tends to be sporadic in nature, and where found in treatment zone wells, are likely associated as byproducts of fermentation of the injectate or other organic matter. The presence of ketones is often an indicator of fermentation reactions which contribute to complete dechlorination of chlorinated VOCs. Vigorous fermentation often occurs under methanogenic conditions, thus elevated ketone presence may correlate with elevated methane concentrations. The transience of these compounds is evident in the monitoring data where most compounds detected peaked in concentration during the treatability study and all had declined to below detection limit by the 12-month event.

MEK was detected in wells 14-MW-3 and 14-MW-10 between months 2 and 9, but was not detected in either well following the 12-month event (see Table A-1 of Appendix A of the IRA Work Plan). Detections of highest MEK concentrations generally corresponded with elevated methane concentrations in the same wells, supporting the interpretation of substrate fermentation under methanogenic conditions. MEK was not detected in wells during the 12-month event, suggesting its presence is transient in the treatment zone.

The compounds 2-hexanone and 4-methyl-2-pentanone were detected in upgradient well 14-MW-2 (3 month event only) and well 14-MW-10 (10-day event only) at concentrations below 2 µg/L (between the method detection and reporting limits), thus they were "j flagged" as estimated concentrations (Table 4 of Attachment A). The presence of these constituents in the background well suggests that processes generating these constituents may be naturally occurring (i.e. not associated with the treatability study).

The detection of acetone is difficult to interpret relative to the treatability study. In the six instances it was detected, three instances were attributed to laboratory contamination in the blank sample analyses, and two instances occurred during the baseline sampling round (i.e. not attributed to substrate degradation). Therefore, its presence relative to the treatability study is limited to a single detection from well 14-MW-10 (9.9 µg/L j) during month 3 (Table 4 of Attachment A).

Carbon disulfide was detected once in well 14-MW-9 (0.12 µg/L j, 2-month event), and twice in well 14-MW-10 (60.9 µg/L, 10-day event; 20.6 µg/L, 3-month event). Its presence only in treatability study wells following substrate injection is attributed to a transient reaction of the substrate. Carbon disulfide is ubiquitous in the environment, and occurs naturally due to microbial activity in anaerobic environments. Its detection is associated with the development of strongly reducing conditions during the course of the treatability study in the presence of carbon and sulfate.

Table 2.3-1
Worksheet for Soybean Oil Mass and Volume Estimate
Phase I Watt Road ESO Program
Site 13 Cluster Interim Removal Action
Vandenberg AFB, California

Assumptions

Length of treatment zone	(feet)	140		
Height of treatment zone	(feet)	40		
Treatment Duration	(years)	4		
Groundwater Velocity	(ft/day)	0.4		
Porosity		0.3		
Treatment Volume	(gallons)	7,338,778		
	(liters)	25,913,224		
Contaminant Concentrations			Demand Factor	H2 Demand
TCE	(mg/L)	0	0.0486	0.00
DCE (combined)	(mg/L)	0.5	0.0416	1.19
perchlorate	(mg/L)	0	0.0811	0.00
sulfate	(mg/L)	50	0.0840	239.62
nitrate	(mg/L)	0	0.0813	0.00
DO	(mg/L)	1	0.1259	7.19
Total H2 Demand	(pounds H2)			248
Engineering Factor				2.5
Approximate Weight of Soybean Oil Required	(pounds)			27,900
Approximate Volume of Soybean Oil Required	**(gallons)**			**3,986**

RESPONSES TO COMMENTS FROM THE DEPARTMENT OF TOXIC SUBSTANCES CONTROL DATED 14 JANUARY 2005 ON THE DRAFT SITE 13 CLUSTER ENGINEERING EVALUATION/COST ANALYSIS

1.1 GENERAL COMMENTS

General Comment 1:

The document contains many acronyms that are not spelled out. Please spell out the acronyms when first used in the text and provide a list of acronyms and abbreviations.

Air Force Response:

A comprehensive acronym list has been created and will be included in the Draft Final version of the Site 13C EE/CA. All acronyms and abbreviations were checked and corrected in the document.

General Comment 2:

The ARARs listed in Table B-1 are general in nature and not specific for each alternative evaluated in the EE/CA. Also, the appropriate citations from the California Code of Regulations (CCR) are not clearly identified or specified in the ARARs table. An evaluation of the ARARs should be made separately for each alternative. The Air Force may provide an additional column in Table B-1 to list alternative(s) that are being evaluated for the particular ARAR. The Attachment to this letter contains the Chemical, Location, and Action-Specific ARARs DTSC has identified for the project, as well as the Advisories, Guidance, and Criteria to be Considered. Please evaluate the provided ARARs for the proposed alternatives.

Air Force Response:

Table B-1 has been modified to accommodate evaluation for each alternative, and has been augmented with the DTSC-provided ARARs. This revised table will be included in the Draft Final EE/CA.

General Comment 3:

Although the IRA is intended to reduce contaminants in groundwater via injection of soy bean and oxygen diffusion, site restoration is essential because excavations/accumulation areas serve as a pathway for contaminants migration from source area(s). VAFB may propose site restoration activities, where appropriate, as part of this IRA.

Air Force Response:

The scope of this IRA is to treat groundwater in the paleochannel downgradient of the source area(s). Contaminant migration from the source area(s) and site restoration will be addressed in a remedial action plan to be prepared during the remedial action phase, following completion of the Site 13 Cluster Feasibility Study.

General Comment 4:

The IRA Work Plan (IRA WP) should be submitted together with the EE/CA in order for DTSC to conduct a comprehensive environmental evaluation of the project and to public notice both documents at the same time to save time and resources

Air Force Response:

As suggested, the Air Force will submit the Draft Final EE/CA and the Draft IRA Work Plan together in a single submittal to save time and resources.

General Comment 5:

Currently the contaminated groundwater at the site is not protective for unrestricted uses. Please include a statement indicating that in order to prevent use of this Site 13C contaminated groundwater as a potable water source before or during remediation, institutional controls are necessary in accordance with California Health and Safety Code Sections 25260 and 25222 1. Also, please include a statement that VAFB will submit a Feasibility Study/Remedial Action Plan (RAP) to document the final remedy for Site 13.

Air Force Response:

The following statements above will be added to the end of Section 4.0 of the Draft Final EE/CA. "In order to prevent use of Site 13C groundwater containing chemical above drinking water standards as a potable water source before or during remediation, institutional controls are necessary in accordance with California Health and Safety Code Sections 25260 and 25222 1. The final remedy for Site 13C will be documented in the Feasibility Study/Remedial Action Plan."

1.2 SPECIFIC COMMENTS

Specific Comment 1:

Section 2 1 Site 28 Description: The document describes a former 60,000-gallon underground tank removed from the site and the accumulation of soil/sediment and rainwater. Please confirm that site restoration activities have been completed to reduce contaminants migration into groundwater. Although the IRA is intended to reduce contaminants in groundwater via injection of soy bean and oxygen diffusion, site restoration is essential because excavations/accumulation serve as a pathway for contaminants migration from source area(s).

Air Force Response:

The EE/CA is limited in scope and addresses volatile organic compound (VOC) contamination in groundwater in the paleochannel area only. Potential contaminants in soil or sediment in the lower Aerozine-50 hardstand at Site 28, located on the mesa above ABRES-A Canyon and the paleochannel, would not be expected to migrate into groundwater because (1) the hardstands are concrete-lined; and (2) there is no groundwater in the mesa area where Site 28 resides (saturated or partially saturated soil on the mesa was encountered only at the end of the concrete-lined portion of Channel C and in the man-made bedrock depression of the former underground fuel dump tank). The Draft Remedial Investigation (RI) Report for Site 13 Cluster includes a baseline risk assessment and provides recommendations for all areas of concern identified at the site, including the hardstands at Site 28. Any future remedial actions for Site 28 will be addressed in the forthcoming feasibility study currently in preparation by Tetra Tech.

Specific Comment 2:

Section 4.5.1.4 Alternative 3.D, Addition of Soybean Oil: The alternative involves the injection of soybean oil in two areas (Watt Road and Southern Pacific Road). The discussion implies that this alternative will be successful for reducing VOCs in the two areas. Please include a statement that this alternative may not be effective to treat the aerobic portion of the aquifer west of the Southern Pacific Railroad Tracks.

Air Force Response:

The following statement will be added to Section 4.5.1.4:

"This alternative may not be effective at the downgradient IRZ due to subsurface aerobic conditions. Because ambient groundwater conditions in the downgradient aquifer are semi-aerobic, this alternative will require large quantities of ESO to be injected, and may require a longer total treatment duration."

Specific Comment 3:

Table 4-2 In-Situ Bioremediation Ranking Summary: Alternative 3.D Soybean Oil Injection and Alternative 3.E iSOC™ and Soybean are both ranked the same yet Alternative 3.D may not be effective to treat the aerobic portion of the aquifer west of the Southern Pacific Railroad Tracks. Please correct the ranking.

Air Force Response:

The ranking has been corrected to reflect the increased cost and duration of soybean oil injection to treat the aerobic portion of the aquifer.

Specific Comment 4:

Section 5.2 Preliminary Schedule: No community outreach activities are proposed for the IRA WP. DTSC recommends that VAFB submit the EE/CA and IRA WP at the same time. See General Comment No. 4.

Air Force Response:

The Air Force will submit the Draft Final EE/CA and Draft IRA Work Plan in a single submittal to save time and resources.

Specific Comment 5:

Please submit the following information to aid DTSC in the preparation of appropriate California Environmental Quality Act (CEQA) documents for the project.

a. Geology: Provide information regarding fault zones in the area and evaluate the impact of seismicity.

b. Hydrology: Please describe to what extent project activities:

i. Would violate any water quality standards or waste discharge requirements

ii. Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficient in aquifer volume or a lowering of the local groundwater table level (e g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted).

iii. Substantially alter the existing drainage pattern of the site or area, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on or offsite.

iv. Otherwise substantially degrade water quality.

c. Ecological Resource: Provide an analysis of potential impact of the IRA on endangered, listed, or threatened species at the site and mitigation measures to reduce impact of the proposed project.

d. Cultural Resources: Provide information regarding cultural resources for Site 13C. Also, include a statement that items of interest such as bones, fossils, or human artifacts of potential historical significance if uncovered during construction of the remedy, a paleontologist or archaeologist will be contacted and field work will resume after all necessary natural resources protective actions are taken.

e. Mineral Resources, Utilities, Transportation and Traffic: Provide an estimate of the natural resource that will be consumed by the project, number of trucks hauling waste, vehicles, traffic flow, loading and transport of wastes, traffic control measures, and duration of project activities.

f. Provide a detailed analysis of the short-term impacts on ecological receptors and mitigation measures to reduce the impacts

Air Force Response:

DTSC Comment 5 has several subparts that are related to CEQA issues; it is not clear whether these are appropriate to include such discussion in the EE/CA for the proposed IRA. State regulatory comments and Air Force responses to these comments, as provided below, are proposed to be included in a new Appendix E to the Draft Final and Final EE/CA, instead of being incorporated into the text of the document. This approach should help maintain the streamlined nature of the document allowing a more readable EE/CA for the public, while at the same time providing DTSC technical information that will support the preparation of CEQA documents.

a. Due to the proximity of known active faults to the project area, the project site is classified as being located in a seismically active area. However, since the proposed "construction" activities are limited to installation of groundwater remediation and monitoring wells, the impact of potential seismic activity is anticipated to present no significant threat. A seismic evaluation is provided below

Active and potentially active faults in the Site region were evaluated by reviewing the *Fault Activity Map of California and Adjacent Areas* (Jennings 1994) and *Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada* (International Conference of Building Officials [ICBO] 1998). Table 1 is a summary of the data on active faults located up to 100 kilometers (km) from the Site that are presented in *Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada* (ICBO 1998) as determined by the computer program, UBCSEIS, Version 1.03 (Blake 1999).

The terms "active" and "inactive" have been interpreted differently by geologists, seismologists, and agencies. For this assessment, active faults are defined as having evidence of surface displacement within the last 11,000 years and potentially active faults are defined as having evidence of surface displacement in the last 1.6 million years (ICBO 1998). Active Faults-Near-Source Zones identified in the Site area, as defined in ICBO 1998, include the Lion's Head fault, approximately 7.6 km northeast of the Site; the Casmalia 10.5 km northeast, the Hosgri 12.0 west, the San Luis Range (south margin) 27.7 km northeast, and the Los Alamos-Baseline fault, approximately 25.5 km northeast. All of these faults are considered Type B active faults (defined as faults with maximum moment magnitudes (Mmax) greater than 7 and slip rates less than 5 millimeters per year (mm/yr), or with Mmax less than 7 and slip rates greater than 2 mm/yr, or with Mmax greater than 6.5 and slip rates greater than 2 mm/yr (ICBO 1998). The nearest Type A active fault (defined as faults with Mmax greater than 7 and slip rates greater than or equal to 5 mm/yr) is the San Andreas-1857 Rupture segment, located approximately 90 km from the Site.

A summary of the California Geological Survey (CGS) historical earthquake record for the Site area from 1800 through 2000 as estimated by the computer program EQSEARCH (Blake 2000) is summarized in Table 2. Historical earthquakes that originated in the Santa Maria region include the Los Alamos earthquakes of 1902 and 1915 (Richter Magnitudes [M_L] 5.4 and 5.2, respectively), the 1916 Avila Beach earthquake (M_L 5), 1927 Lompoc earthquake (M_L 7.0), and the 1980 Point Sal Earthquake (M_L 5.1). While all of these earthquakes were felt in the Site area, no historical earthquakes have caused a great amount of property damage or loss of human life in the Site area. As shown in Table 2, the earthquake reoccurrence interval for the last 200 years based on the CGS database ranged from once every 1.78 years for M_L 4.0 earthquakes to once every 100.5 years M_L 7.5 earthquakes. However, the historical earthquake record of California spans less than 200 years and provides only a partial indication of seismic hazards. The absence of earthquakes on many recognized active faults and fault-related folds in California probably reflects more frequent recurrence intervals than the historical record. In addition, there is a potential for earthquakes to occur in areas with blind thrust faults or other concealed seismogenic structures that may not have been previously recognized (Clark *et al.* 1994).

A more recent notable earthquake that is not included in the EQSEARCH database was the San Simeon earthquake (M_L 6.5) that occurred December 22, 2003. This earthquake occurred on an undetermined fault approximately 100 km north of the Site and caused substantial damage to buildings in San Luis Obispo County and two deaths in the community of Paso Robles. This earthquake caused light to moderate shaking in the Site area; however, no property damage or deaths were reported for Vandenberg AFB from this earthquake.

Surface fault rupture hazards for the Site area were evaluated through examining Special Study Zone Maps created under the Alquist-Priolo Earthquake Fault Zoning Act (AP Act). The AP Act, addressees the seismic hazard of surface fault rupture and prohibits the placement of structures across traces of active faults. Under the AP Act, Special Study Zone Maps are created to delineate special AP Zone Fault Zone study areas around known active faults. There are no Special Study Zone Maps for the Site area, and no known active faults extend across the Site. The closest AP Zone Fault Zone to the Site is along the Los Alamos-Baseline fault, approximately the 26 kilometers to the northeast (*Digital Images of Official Maps of Alquist-Priolo Earthquake Fault Zones of California, Southern Region* (California Division of Mines and Geology [CDMG] 2000)

Potential structural damage from landslides are related to regional seismic activity. The Site is located in the northwestern portion of Burton Mesa on a plateau between a canyon along San Antonio Creek to the north and an unnamed canyon to the south. The slopes at the Site range from almost horizontal on top of the plateau to 2.3:1 (H:V) on the slopes from the plateau into the canyons to the north and south. No landslides are identified at the Site on the 1989 geologic map of the Site area prepared by Thomas Dibblee (Dibblee 1989). Most of the geologic formations that occur at the Site are not known to be particularly prone to landslides. The geologic formations at the Site include Pleistocene Orcutt Sand exposed at the ground surface on top of the plateau, underlain by Pliocene/Miocene Sisquoc and Miocene Monterey Formation at depth, and Quaternary alluvium derived largely from Orcutt Sand in the bottom of canyons on the north and south sides of the Site. The Monterey formation can pose a significant landslide hazard in areas of steep topography, such as the canyon slopes on the south side of the plateau. Because of the presence of the Monterey Formation and moderately steep slopes present at the Site, the landslide hazard at the Site may be considered to be minimal on top of the plateau away from the canyon slopes to moderate in the canyon-slope areas.

Tsunamis are large and destructive waves in the ocean caused by seafloor movement from earthquakes and landslides. Although the Site is located approximately only 1.5 miles from the Pacific Ocean, in the event of a tsunami reaching the coast of Vandenberg AFB, it is not likely that the Site would be affected due to its surface elevation. (approximately 100 to 200 feet above msl).

Liquefaction is related to regional seismic activity. It is caused is the significant loss of soil strength due to pore pressure increase from ground shaking which reorients unconsolidated sediment grains into a more compact arrangement. If the water table is close to the surface during this reorientation, the grain-to-grain contacts are reduced and the load is temporarily transferred to the pore water. This increases pore pressure, decreases the strength, and the deposit then behaves like a liquid (Costa and Baker 1981). Liquefaction may occur when groundwater is present at depths less than 50 feet bgs within the potentially liquefiable material, the soil is granular and meets a specified range of grain sizes, and the soil is in a loose state of low relative density. If these conditions are present and strong ground motion occurs, portions of the soil column could liquefy, depending on the intensity and duration of the strong ground motion. Soils most susceptible to liquefaction are saturated, very loose to loose, fine grained sandy and silty soils. Liquefaction may manifest itself at the surface as lateral spreading, sand boils, lurching and ground fissuring, loss of bearing strength, and settlement. Any structures founded on or above potentially liquefiable soils may experience settling (both total and differential) and loss of foundation support during ground shaking. At present there are no known areas on Vandenberg AFB where liquefaction has occurred (U. S. Air Force 1987). Due to the >50 foot depth of water in the paleochannel area where the IRA is situated, the potential for liquefaction is low.

bi The project is not anticipated to violate water quality standards or waste discharge requirements Waste discharge requirements will not be violated by the in-situ groundwater remediation project. There will be no water, hazardous materials, or non-hazardous material (e g., vegetable oil) discharged to the surface. Groundwater will not be allowed to discharge on the ground surface during well development activities.

bii. Because the project involves introduction of fluids into groundwater, the project is not anticipated to have any affect on water supply wells or interfere with groundwater recharge such that there would be a net deficit in aquifer volume The nearest water supply wells (designated San Antonio Wells No. 4, 5, 6 and 7A) are located in Barka Slough, approximately 7.5 miles east and upgradient of the site. Groundwater at the site is not extracted for use as a drinking water source. The goal of the remedy will improve water quality downgradient of the barriers. The project will not adversely affect existing land uses or planned uses for which permits have been granted.

biii The *in-situ* project will not alter the existing drainage pattern of the area. The rate or amount of surface runoff will not be increased as a result of the project and will not result in flooding on or off-site.

biv. The proposed in-situ groundwater remediation project is designed to improve rather than degrade groundwater quality by degrading chlorinated solvents in groundwater. The amendments added to the groundwater are designed to be consumed by microbacteria during the bioremediation program.

c. The Table in Attachment I of this document lists species present or potentially present in habitats observed at Site 13 Cluster (U.S Air Force 2004). A Form 35 Permit (dig permit) will be required before construction or drilling commences. The Form 35 permit application is reviewed by 30 CES/CEV Environmental Flight who will determine the need for biological monitoring. The project will not be detrimental to animal life. Short-term land disturbance would occur at the site during well drilling and injection of the edible vegetable oil that may temporarily affect localized habitat use. The remedy will not reduce the size of habitats for any receptors. Equipment operation and travel will be limited to only what is necessary to complete the IRA to minimize impacts to on-site vegetation. If vegetation areas are significantly disturbed, they will be restored as necessary once the remedy is complete.

d. A Form 35 Permit will be required before construction commences The Form 35 permit application is reviewed by 30 CES/CEV Environmental Flight. The Vandenberg AFB Environmental Flight checks the project area for potential and known cultural resources before approving the construction. Cultural resources have been identified in the paleochannel area. Therefore, an archaeological monitor will be present, as required, during field activities to ensure that items of interest such as bones, fossils, or human artifacts of potential historical significance (if encountered) are protected. Fieldwork will resume only after necessary protective actions are taken.

e. The proposed in-situ groundwater remediation project will require transportation of vehicles and equipment to and from the project area. Consumption of natural resources (fossil fuels) during this project will be limited to those associated with these transportation activities. It is estimated that the average daily traffic flow to this project area will increase by three automobile round trips and four truck round trips during the duration of the project. The minimal increase in traffic volume associated with this project will not impact normal traffic flow or traffic patterns at the, or on the route to, the project site. Additionally, no traffic control measures are expected to be required to complete this project.

It is estimated that 10 truck loads of waste soil cuttings generated during the well installation phase of this project will be loaded on-site and transported to the Vandenberg AFB landfill for disposal. The loading and transportation of this waste is not expected to have negative impacts on traffic flow or traffic patterns at the, or on the route to, the project site

f As mentioned previously, there are no expected short-term or long-term impacts on ecological receptors as a result of the project (see response to comment b above)

REFERENCES

Blake, Thomas F.

1998 *UBCSEIS, A Computer Program for the Estimation of Uniform Building Code Coefficients Using 3-D Fault Sources.*

Blake, Thomas F.

1999 *EQSEARCH, A Computer Program for the Estimation of peak Horizontal Acceleration from California Historical Earthquake Records.*

California Department of Conservation, Division of Mines and Geology (CDMG)

1972, revised 1997, updated 1999, 2003 *Special Publication No 42, Alquist-Priolo Earthquake Fault Zoning Act*

California Division of Mines and Geology (CDMG)

2000 *Digital Images of Official Maps of Alquist-Priolo Earthquake Fault Zones of California, Southern Region.*

Clark, D G , D B Slemmons, S J Caskey, and D M. dePolo

1994 *Seismotechtonic Framework of Coastal Central California* Geological Society of America Special Paper No. 292

Costa, J E. and V R. Baker

1981 *Surficial Geology, Building With the Earth.* John Wiley & Sons, Canada.

Dibblee, Thomas W. Jr.

1989 *Geologic Map of the Casmalia and Orcutt Quadrangles* Dibblee Geological Foundation, Santa Barbara, California.

International Conference of Building Officials (ICBO)

1998 *Maps of Known Active Fault Near-Source Zones in California and Adjacent Portions of Nevada.*

Jennings, Charles W.

1994 *Fault Activity Map of California and Adjacent Areas,* California Department of Conservation, Division of Mines and Geology California Geologic Data Map Series Map No. 06.

U S. Air Force

1987 Mineral Resource Management Plan (Final), Potential Exploration, Development, and Production of the Oil and Gas. Vandenberg AFB, California.

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Table 1
Regional Fault Characteristics

Fault Name and Section	Approximate Distance from Site (kilometers)	Seismic Source Type	Maximum Magnitude (Mmax)	Slip Rate (mm/yr)	Fault Type
LIONS HEAD	7.6	B	6.6	0.02	DS
CASMALIA (Orcutt Frontal Fault)	10.5	B	6.5	0.25	DS
HOSGRI	12	B	7.3	2.5	SS
LOS ALAMOS-W. BASELINE	25.5	B	6.8	0.7	DS
SAN LUIS RANGE (S. Margin)	27.7	B	7	0.2	DS
LOS OSOS	30	B	6.8	0.5	DS
SANTA YNEZ (West)	40.2	B	6.9	2	SS
RINCONADA	59.1	B	7.3	1	SS
SAN JUAN	71.4	B	7	1	SS
M.RIDGE-ARROYO PARIDA-SANTA ANA	73.6	B	6.7	0.4	DS
SANTA ROSA ISLAND	83.6	B	6.9	1	DS
SAN ANDREAS - 1857 Rupture	89.6	A	7.8	34	SS
SANTA CRUZ ISLAND	91.9	B	6.8	1	DS
SANTA YNEZ (East)	94.4	B	7	2	SS
RED MOUNTAIN	95.6	B	6.8	2	DS
VENTURA - PITAS POINT	108	B	6.8	1	DS

Notes: - The data presented in this table are from the data file "CDMGUBCR" from the UBCSEIS computer program (Blake 1998). The data file is based on information from *Maps of Known Active Fault Near-Source Zones in California and Adjacent Parts of Nevada to be Used with the 1997 Uniform Building Code* (ICBO 1998).

A - Faults with a MwMax = 7 and a slip rate = 5 mm/yr.
B - Faults with a MwMax = 7 and a slip rate < 5 mm/yr, MwMax < 7 and a slip rate > 2, or MwMax= 6.5 and a slip rate < 2mm/yr.
DS - dip slip fault
IC - International Conference of Building Officials
mm/yr - millimeters per year
Mmax - Fault segment earthquake maximum magnitude as defined in *Maps of Known Active Fault Near-Source Zones in California and Adjacent Parts of Nevada to be Used with the 1997 Uniform Building Code* (ICBO 1998)
MwMax - Maximum earthquake moment magnitued (Mw) where Mw is equal to the rigidity of the earth times the average amount of slip on the fault times the amount of fault area that slipped (http://earthquake.usgs.gov/recenteqsww/glossary.htm)
SS - strike slip fault

Table 2
Historic Earthquake Catalogue Data Summary

Earthquake Location Latitude North	Longitude West	Earthquake Date	Earthquake Magnitude (M_L)	Estimated Site PGA (g)	Modified Mercalli Intensity (MM)	Approxin Distance From Site mi (km)
34.833	120.583	10/16/1936	4	0.114	VII	3.8(6.1)
34.883	120.683	2/1/1962	4.5	0.095	VII	8.4(13.5)
34.857	120.47	6/21/1966	4.1	0.072	VII	9.2(14.7)
34.667	120.5	6/13/1944	4.6	0.09	VII	9.8(15.7)
34.667	120.5	6/13/1944	4.4	0.081	VII	9.8(15.7)
34.667	120.5	6/13/1944	4	0.066	VI	9.8(15.7)
34.9	120.7	11/4/1927	7.5	0.412	X	9.9(15.9)
34.849	120.774	2/16/1937	4	0.061	VI	10.8(17.4)
34.717	120.417	11/30/1944	4.1	0.062	VI	11.4(18.4)
34.8	120.4	12/12/1902	5.7	0.143	VIII	11.6(18.6)
34.6	120.7	12/31/1927	4	0.052	VI	13.7(22.0)
34.6	120.7	12/5/1927	4.3	0.061	VI	13.7(22.0)
34.9	120.4	3/29/1928	5.3	0.1	VII	14.1(22.7)
34.868	120.376	9/23/1982	4	0.05	VI	14.2(22.8)
34.918	120.8	6/20/1984	4.2	0.055	VI	14.6(23.6)
34.931	120.819	5/29/1980	4.7	0.066	VI	16.0(25.8)
35	120.5	7/26/1917	4	0.046	VI	16.2(26.1)
35	120.5	11/19/1927	5	0.077	VII	16.2(26.1)
34.6	120.4	7/28/1902	6.3	0.148	VIII	17.0(27.3)
34.6	120.4	8/1/1902	6.3	0.148	VIII	17.0(27.3)
34.8	120.3	9/11/1902	4	0.044	VI	17.2(27.7)
34.8	120.3	9/11/1902	4	0.044	VI	17.2(27
34.7	120.3	7/31/1902	5.5	0.093	VII	18.0(29
34.7	120.3	1/12/1915	5.5	0.093	VII	18.0(29.0)
34.55	120.783	6/16/1940	4	0.041	V	18.9(30.5)
34.55	120.783	3/19/1935	4	0.041	V	18.9(30.5)
34.55	120.783	9/29/1938	4	0.041	V	18.9(30.5)
34.55	120.783	10/17/1939	4	0.041	V	18.9(30.5)
34.5	120.5	8/27/1949	4.9	0.062	VI	20.2(32.6)
34.5	120.5	8/26/1949	4.2	0.043	VI	20.2(32.6)
34.583	120.333	12/17/1934	4.5	0.05	VI	20.5(33.0)
34.583	120.333	12/18/1934	4	0.038	V	20.5(33.0)
34.5	120.8	12/24/1937	4	0.036	V	22.4(36.0)
34.461	120.521	11/18/1936	4.5	0.046	VI	22.6(36.3)
34.456	120.521	10/1/1959	4.5	0.046	VI	22.9(36.9)
34.445	120.467	9/9/1936	4	0.033	V	24.4(39.3)
34.737	120.148	10/25/1984	4.5	0.042	VI	26.0(41.8)
34.736	120.147	11/6/1986	4	0.032	V	26.0(41.9)
35	121	3/27/1947	4.2	0.034	V	27.1(43.6)
35.17	120.75	12/1/1916	5.7	0.074	VII	28.1(45.3)
34.37	120.623	11/22/1937	4.5	0.039	V	28.4(45.7)
35.2	120.6	10/20/1913	4	0.029	V	28.9(46.6)
34.7	120.1	7/28/1945	4.2	0.033	V	29.1(46.8)
35.25	120.67	9/5/1922	4	0.027	V	32.6(52.5)
35.25	120.67	6/28/1920	4	0.027	V	32.6(52.5)
35.25	120.67	12/15/1869	4.3	0.031	V	32.6(52.5)
35.25	120.67	7/21/1931	4	0.027	V	32.6(52
35.25	120.67	5/4/1923	4	0.027	V	32.6(52
35.25	120.67	00/00/1830	5.7	0.066	VI	32.6(52.5)
35.25	120.67	12/17/1852	5.7	0.066	VI	32.6(52.5)
35.25	120.5	7/9/1917	5.3	0.053	VI	32.9(52.9)

Table 2
Historic Earthquake Catalogue Data Summary

Earthquake Location		Earthquake	Earthquake	Estimated Site	Modified	Approximate
L ..ude North	Longitude West	Date	Magnitude (M_L)	PGA (g)	Mercalli Intensity (MM)	Distance From Site mi (km)
35 25	120 5	7/9/1917	5	0 045	VI	32 9(52 9)
35 25	120 5	7/10/1917	5 3	0 053	VI	32 9(52 9)
35 25	120 5	7/10/1917	5 3	0 053	VI	32 9(52 9)
34 365	120 888	6/12/1969	4	0 027	V	33 0(53 1)
35 28	120 48	5/21/1940	4	0 025	V	35 1(56 6)
35 3	120 7	12/7/1906	5 9	0 067	VI	36 3(58 3)
34 661	119 973	5/7/1984	4 2	0 027	V	36 7(59 0)
34 232	120 662	11/1/1936	4	0 024	IV	38 0(61 2)
34 291	120 938	1/9/1989	4 1	0 025	V	38 8(62 5)
34 855	121 319	10/23/1969	4 1	0 024	IV	40 9(65 9)
34 707	121 377	12/3/1969	4	0 021	IV	44 2(71 2)
34 649	121 389	11/10/1969	4	0 021	IV	45 5(73 3)
34 653	121 41	11/9/1969	4 1	0 021	IV	46 7(75 1)
34 744	121 446	11/5/1969	4 5	0 026	V	47 9(77 1)
35 47	120 75	2/3/1953	4 1	0 021	IV	48 3(77 7)
34 609	121 435	11/5/1969	5 6	0 046	VI	48 7(78 4)
34 5	121 4	4/3/1944	4	0 02	IV	49 3(79 3)
35 5	120 6	01/01/1830	5	0 033	V	49 6(79 9)
35 5	120 5	6/4/1953	4 3	0 023	IV	50 0(80 4)
34 42	119 82	00/00/1862	5 7	0 047	VI	51 0(82 0)
34 754	121 515	10/28/1969	4	0 019	IV	51 8(83 3)
34 402	119 802	3/10/1986	4 1	0 02	IV	52 5(84 5)
4 471	119 757	11/16/1958	4	0 019	IV	52 6(84 6)
34 4	119 8	9/9/1929	4 6	0 025	V	52 7(84 7)
35 5	120 92	11/27/1946	4 3	0 022	IV	52 8(84 9)
34 333	119 833	6/26/1933	4 3	0 021	IV	53 6(86 2)
34 333	119 833	6/26/1933	4 3	0 021	IV	53 6(86 2)
35 4	121 2	1/2/1960	4	0 018	IV	54 5(87 6)
34 5	119 7	7/29/1925	4	0 018	IV	54 8(88 2)
34 5	119 7	8/26/1919	4	0 018	IV	54 8(88 2)
34 5	119 7	8/26/1919	4	0 018	IV	54 8(88 2)
34	120 4	3/29/1911	4 6	0 025	V	55 1(88 7)
34 49	119 691	9/16/1962	4	0 018	IV	55 5(89 4)
34 35	119 767	11/10/1940	4	0 018	IV	56 1(90 2)
34 589	121 565	10/22/1969	4	0 018	IV	56 2(90 5)
34 5	119 67	06/25/1855	4 3	0 021	IV	56 4(90 8)
34 5	119 67	05/31/1854	4 3	0 021	IV	56 4(90 8)
34 5	119 67	2/9/1902	4 3	0 021	IV	56 4(90 8)
34 5	119 67	07/09/1885	4 3	0 021	IV	56 4(90 8)
34 5	119 67	06/01/1893	5	0 03	V	56 4(90 8)
34 5	119 67	03/14/1857	4 3	0 021	IV	56 4(90 8)
34 3	119 8	6/29/1925	6 25	0 057	VI	56 4(90 8)
34 3	119 8	7/3/1925	5 3	0 035	V	56 4(90 8)
34 3	119 8	7/3/1925	5 3	0 035	V	56 4(90 8)
34 598	121 586	10/24/1969	4	0 017	IV	57 2(92 1)
34 325	119 761	8/9/1956	4	0 017	IV	57 3(92 2)
33 955	120 71	12/3/1937	4	0 017	IV	57 3(92 3)
5 6	120 8	6/29/1942	4	0 017	IV	57 6(92 8)
34 4	119 7	6/24/1926	4	0 017	IV	57 6(92 8)
34 4	119 7	8/26/1927	4	0 017	IV	57 6(92 8)
34.4	119.7	7/6/1926	4	0.017	IV	57.6(92.8)

Table 2
Historic Earthquake Catalogue Data Summary

Earthquake Location Latitude North	Longitude West	Earthquake Date	Earthquake Magnitude (M_L)	Estimated Site PGA (g)	Modified Mercalli Intensity (MM)	Approximate Distance From Site mi (km)
34 4	119.7	03/25/1806	5	0.029	V	57 6(92.8)
34.4	119 7	8/9/1926	4	0 017	IV	57.6(92 8)
35 3	119 8	01/09/1857	7 9	0 135	VIII	57 8(93 0)
34 6	121.6	3/5/1962	4.5	0.022	IV	58.0(93.3)
34 6	121 6	3/10/1962	4.2	0 019	IV	58.0(93 3)
34 6	121 6	3/10/1962	4	0 017	IV	58 0(93 3)
34.576	121.62	10/22/1969	5.4	0 035	V	59.5(95.7)
34 347	119.696	8/13/1978	5.1	0 03	V	59 6(95.9)
34 317	119.7	10/21/1953	4	0 017	IV	60 5(97 4)
34.2	119 8	12/21/1812	7	0 081	VII	60.8(97.8)
35.67	120.67	9/8/1915	4	0.016	IV	61.5(99.0)

Summary

Earthquake Magnitude Range (M_L):	
Minimum	4.00
Maximum	9 00
Site Coordinates:	
Latitude:	34.7809
Longitude:	120 6026
Search Time Period:	1800 - 2000
Approx. Search Radius in mi(km):	62 (100)
Nearest Earthquake Distance in mi(km):	3 8 (6 1)
Largest Earthquake Magnitude (M_L):	7.9
Largest Estimated Site Acceleration (g)	0.412

Earthquake Magnitudes and Exceedances

Earthquake Magnitude (M_L)	Number of Times Exceeded	Cumulative No./Year	Cumulative Recurrence Interval (years)
4	113	0.56219	1.78
4 5	41	0 20398	4 90
5	28	0.1393	7 18
5.5	15	0.07463	13 40
6	6	0 02985	33.50
6.5	3	0 01493	66 98
7	3	0.01493	66.98
7.5	2	0.00995	100.50

Notes: - The data presented in this table are from the data file "ALLQUAKE" from the EQSEARCH computer program (Blake 2000). The data file is based on information from the California Geologic Survey (CGS) computerized historic earthquake catalogue for the State of California compiled through 2000.

g - Standard acceleration of gravity where g = 9 81 meters/second as estimated using a deterministic method.

km - kilometer

mi - mile

MM - Modified Mercalli Scale. An earthquake intensity scale having twelve divisions ranging from I (not felt by people) to XII (damage nearly total).

M_L - Richter Scale. A logarithmic scale of earthquake magnitude where the magnitude is the logarithm to base ten of the maximum seismic wave amplitude (in thousandths of a millimeter) measured on a standard seismograph 100 kilometers

PGA - Peak Ground Acceleration using the probabilistic method in EQSEARCH (Blake 2000).

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Chemical-Specific ARARs						
Safe Drinking Water Act, 42 USC 300						
1	National Primary Drinking Water Standards	40 CFR, Part 141	Establishes maximum contaminant levels (MCLs) for public water systems	Relevant & Appropriate	The NCP defines MCLs as relevant and appropriate for groundwater determined to be a current or potential source of drinking water in cases where MCLGs are not ARARs. Groundwater in the vicinity of VAFB has been designated for potential drinking water use.	1, 2, 3, 4, 5
2	Maximum Contaminant Level Goals (MCLGs)	40 CFR, Part 141	Establishes potable water quality goals.	Relevant & Appropriate	MCLGs that have non-zero values are relevant and appropriate for groundwater to be a current or potential source of drinking water. Groundwater in the vicinity of VAFB has been designated for potential drinking water use.	1, 2, 3, 4, 5
Clean Water Act, 33 USC 1251 et seq.						
3	Water Quality Standards and Criteria	33 USC, 1313 and 57, Federal Register 60920-60921	Establishes the requirement of water quality standards for discharges to waters of the United States	Potentially Relevant & Appropriate	Applies to any potential site discharge to waters of the United States.	2, 3, 4, 5
Hazardous Waste Control Act (HWCA)						
4	Concentration limits of regulated units effluent to groundwater, surface water, and soil	Title 22, CCR, Div 4.5, Ch 14, §66264.94	Groundwater and vadose zone protection standards: RCRA hazardous waste TSD facilities shall comply and ensure that hazardous constituents entering the groundwater, surface water, and soil from a regulated unit do not exceed the concentration limit from contaminants of concern in the uppermost aquifer underlying the waste management area beyond the point of compliance.	Potentially Relevant & Appropriate	Applicable for hazardous waste TSD facilities; potentially relevant and in site-specific circumstances, such as when the source of waste is unknown but the waste is similar in composition to listed waste or when waste constituents have released or have the potential to release to groundwater. This site is not a TSD facility, and existing concentrations of constituents present in site mdeia are generally below levels that would classify them as hazardous waste.	2, 3, 4, 5
5	Hazardous waste listing and identification	Title 22, CCR, Div 4.5, Ch 11, §66261.2, §66261.3	Identification of hazardous waste that poses a potential hazard to human health or the environment when it is improperly treated, stored, transported, or disposed.	Potentially Relevant & Appropriate	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made at the time that wastes are generated.	2, 3, 4, 5
Resource Conservation and Recovery Act (RCRA)						
6	RCRA Hazardous Waste and toxic characteristics leaching procedure (TCLP) levels	Title 22, CCR	Defines RCRA hazardous waste and TCLP regulatory levels.	Potentially Relevant & Appropriate	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made at the time that wastes are generated.	2, 3, 4, 5
Cal/EPA DTSC						
7	Non RCRA Hazardous Waste; persistent and bioaccumulative toxic substances, total threshold limit concentrations (TTLCs), and soluble threshold limit concentrations (STLCs).	Title 22, CCR, Div 4.5, Ch. 11	Defines non-RCRA hazardous waste, persistent and bioaccumulative toxic substances, and regulatory levels for TTLC and STLC analyses.	Applicable	Hazardous waste determinations for soil cuttings generated from well installations and any extracted groundwater (e.g., purge water) will be made the time that wastes are generated.	2, 3, 4, 5
8	State maximum contaminant level (MCL) list	Title 22, CCR, Div 4, Ch. 15	The primary MCLs are drinking water quality standards established by the U.S. EPA und the Safe Drinking Water Act, the State of California under Domestic Water Quality and Monitoring Regulations. Primary MCLs present risk to the human health when used for drinking or culinary purposes.	Relevant & Appropriate	State MCLs are tap water standards that are relevant and appropriate for the potential drinking water aquifers at VAFB.	2, 3, 4, 5
9	State Secondary MCL list	Title 22, CCR, Div 4, Ch15	Secondary MCLs may be objectionable to an appreciable number of people but are not generally hazardous to human health.	Potentially Relevant & Appropriate	None of the chemicals of concern for the Site 13C EE/CA have secondary MCLs.	1, 2, 3, 4, 5
State and Regional Water Quality Control Board (RWQCB)						
10	Porter Cologne Water Quality Control Act (California Water Code Sections 13240, 13241, 13242, 13243)	Water Quality Control Plan (Basin Plan) for the RWQCB, CCR includes the State Water Resources Control Board's Water Quality Control Plan for Ocean Waters of California (Ocean Plan)	Establishes water quality objectives, including narrative and numerical standards, that protect the beneficial uses and water quality objectives of surface and ground waters in the region. Describes implementation plans and other control measures designed to ensure compliance with statewide plans and policies and provide comprehensive water quality planning.	Applicable	Specific applicable portions of the Basin Plan include beneficial uses of affected water bodies and water quality objectives to protect those uses. Any activity, including, but not limited to, the discharge of contaminated soils or waters or in-situ treatment or containment of contaminated soils or waters, must not result in actual water quality exceeding water quality objectives. The Basin Plan for RWQCB CCR assigns the beneficial use of drinking water to all groundwater in the region (with the exception of the Soda Lake sub-basin). The Basin Plan supersedes Resolution 88-63, therefore, the beneficial use of drinking water must be protected regardless of the Resolution's criteria.	2, 3, 4, 5
11	Porter Cologne Water Quality Control Act (California Water Code Sections 13000, 13140, 13240)	State Water Resources Control Board Resolution (SWRCB) 88-63 (Source of Drinking Water Policy)	Designates all ground and surface waters of the State as drinking water except where the TDS is greater than 3,000 ppm, the well yield is less than 200 gpd from a single well, the water is a geothermal resource or in a water conveyance facility, or the water cannot reasonably be treated for domestic purposes using either best management practices or be economically achievable treatment practices.	Applicable	Applies in determining beneficial uses for waters that may be affected by discharges of waste. The groundwater at VAFB has been identified as a source of drinking water.	1, 2, 3, 4, 5

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Chemical-Specific ARARs						
State and Regional Water Quality Control Board (RWQCB)						
12	Policy Regarding Maintenance of Water Quality in California	SWRCB Resolution 68-16 (Policy with Respect to Maintaining High Quality Waters in California)	Requires that quality of waters of the State is better than needed to protect all beneficial uses be maintained unless certain findings are made. Discharges to high quality waters must be treated using best practicable treatment or controls necessary to prevent pollution or nuisance and to maintain the highest quality water. Requires cleanup to background water quality or to lowest concentrations technically and economically feasible to achieve Beneficial uses must, at least, be protected.	Applicable	Applicable for any surface discharge or subsurface injection of treated wat	3, 4, 5
13	Porter-Cologne Water Quality Control Act	Water Code, Div. 7, §13000 et seq.	Establishes authority of State and Regional Water Boards to protect water quality by regulating waste disposal and requiring cleanup of hazardous conditions that affect waters of the state. Defines designated waste; sets requirements for laboratories; sets report requirements for waste discharges and specifies well drilling requirements and reporting.	Applicable	Defines waste and sets requirements for investigations and analyses.	2, 3, 4, 5
14	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20400. Title 23, CCR, §2550.4.	Concentration limits must be established for groundwater, surface water, and the unsaturated zone. Must be based on background, equal to background, or for corrective actions, may be greater than background, not to exceed the lower of the applicable water quality objective or the concentration technologically or economically achievable. Specific factors must be considered in setting cleanup standards above background levels.	Applicable	Applies in setting ground water cleanup levels for any discharges of waste land.	3, 4, 5
15	California Safe Drinking Water Act (California Health & Safety Code Section 4010 et seq.)	Title 22, CCR, §64400 et seq.	Requirements for public water systems. Includes MCLs and Secondary MCLs.	Relevant & Appropriate	The act is legally applicable for an aquifer and associated distribution and pre-treatment system that is currently defined as "public water system" If it is only a potential "Public water system," then the act is relevant and appropriate.	N/A
16	Safe Drinking Water & Toxic Enforcement Act (aka Prop. 65)	Health and Safety Code, Division 20, Chapt. 6.6, §25249.5 et seq.	Prohibits discharges of specified carcinogens and reproductive toxins into current or potential drinking water sources.	Relevant & Appropriate	Prohibits discharges of specific substances to drinking water sources.	2, 3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Guidance for Ecological Risk Assessment at Hazardous Waste Sites and Permitted Facilities*
DTSC Human and Ecological Risk Division

2 *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities*
DTSC Human and Ecological Risk Division

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Location-Specific ARARs						
17	National Archaeological and Historical Preservation Act	16 USC, 469a-1 and 36 CFR 65	Construction on previously undisturbed land would require an archaeological survey of the area	Applicable	Archaeological surveys have been conducted at VAFB: archaeological monitors should to be present to clear all drilling locations in order to prote cultural resources.	3, 4, 5
18	Endangered Species Act of 1973	16 USC, 1536(a)	Action to protect critical habitat upon which endangered species or threatened species depend must be taken.	Applicable	Sensitive habitat mitigation measures will be followed during implementation of this IRA including the migration patterns of the Snowy Plover.	3, 4, 5
19	Fish and Game Code	Fish and Game Code, §2080	No person shall import, export, take, possess, or sell any endangered or threatened species or part of product thereof.	Potentially Applicable	Endangered species are present at VAFB such as the Claifornia Red-legged Frog and the Snowy Plover.	1, 2, 3, 4, 5
20	Within 200 feet of a fault displacement in Holocene time	Title 22, CCR, Div 4.5, Ch 14, §66264.18	New facility for treatment, storage, or disposal of hazardous waste prohibited.	Potentially Relevant & Appropriate	The location requirements are considered relevant and appropriate for the siting of remedial systems to reduce the toxicity, volume and/or mobility of chemicals.	3
21	Within a 100-year floodplain	Title 22, CCR, Div 4.5, Ch 14, §66264.18	Facility must be designed, constructed, operated, and maintained to prevent washout by flood or maximum high tide	Potentially Relevant & Appropriate	Same as above	3
22	Porter-Cologne Water Quality Control Act (California Water Code Section 13000 et seq.	California Water Code, §13243	The RWQCB may specify certain conditions or areas where the discharge of waste, or certain types of waste, will not be permitted	Applicable	Applies to groundwater remedial action.	3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Drilling, Coring, Sampling and Logging at Hazardous Substance Release sites*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

2 *Reporting Hydrogeologic Characterization Data at Hazardous Substance Release sites*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

3 *Guidelines for Hydrogeologic Characterization of Hazardous Substance Release Sites, Volume 1 & 2*
Cal/EPA, July 1995

4 *Aquifer Testing for Hydrogeologic Characterization*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

5 *Application of Borehole Geophysics at Hazardous Substance Release Sites*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

6 *Ground Water Modeling for Hydrogeologic Characterization*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

7 *Monitoring Well Design and Construction for Hydrogeologic Characterization*
Guidance Manual for Ground Water Investigations
Cal/EPA, July 1995

8 *Advisory – Active Soil Gas Investigation*
DTSC/CRWQCB-Los Angeles Region, January 2003

9 *Representative Sampling of Ground Water for Hazardous Substances*
Cal/EPA, July 1995

10 *Accumulating Hazardous Waste at Generator Sites*
Cal/EPA, July 1995

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
23	Offsite Management Requirements for CERCLA Wastes	58 CFR 49200-49218 40 CFR 300.440	Establishes requirements for managing CERCLA response action wastes at offsite Treatment, Storage and Disposal (TSD) facilities.	Applicable	Applicable for off-site treatment or disposal of removed materials (e.g., drill cuttings, construction materials, or purge waters).	2, 3, 4, 5
24	National Pollutant Discharge Elimination System (NPDES)	40 CFR Parts 122-125	Requires permits for the discharge of pollutants from any point source into the waters of the United States.	Relevant & Appropriate	Best management practices will be implemented to protect storm water discharges.	5
25	Hazardous Waste Control Act (HWCA)	Title 22, CCR, Div 4.5, §66262.10(a), §66262.11	Requires that the generator shall determine if a waste is hazardous waste.	Applicable	Applicable for any operation where waste is generated.	2, 3, 4, 5
26	HWCA	Title 22, CCR, Div, 4.5, §66262.34	Generator may accumulate waste on site for 90 days or less or must comply with requirements for operating a storage facility	Applicable	No storage of hazardous waste is planned as part of this IRA. Accumulatic of hazardous wastes on site for longer that 90 days would be subject to RCRA requirements for storage facilities.	2, 3, 4, 5
27	HWCA	Title 22, CCR, Div 4.5, §66262.40, §66262.41	Generator must keep records of manifests, test results and waste analyses.	Applicable	Applicability of this requirement is contingent upon generation and management of hazardous waste	2, 3, 4, 5
28	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.12	A generator shall not treat, store, dispose of, transport or offer for transportation, hazardous waste without having received an identification number.	Applicable	Applicable for any operation where waste is generated. The determination of whether wastes generated during remedial activities are hazardous shall be made when the wastes are generated.	2, 3, 4, 5
29	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.20, §66262.22	A generator of hazardous waste who transports or offers hazardous waste for transportatic shall prepare a manifest.	Applicable	Same as above.	2, 3, 4, 5
30	HWCA	Title 22, CCR, Div 4.5, Ch 12, §66262.30, §66262.31, §66262.32, and §66262.33	Before transporting hazardous waste or offering hazardous waste for transportation off-site, the generator must do the following in accordance with DOT regulations: package the waste, label and mark each package of hazardous waste, and ensure that the transport vehicle is correctly placarded.	Applicable	Same as above.	2, 3, 4, 5
31	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 2	Establish requirements for a hazardous waste treatment facility to have a plan for waste analysis, develop a security system, conduct regular inspections, provide training to facility personnel, and use a quality assurance program during construction.	Potentially Relevant & Appropriate	Site 13 Cluster is not a TSD facility. The determination of whether wastes generated during remedial activities are hazardous shall be made when the wastes are generated.	2, 3, 4, 5
32	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 3, 4	Establish requirements for a facility to plan for emergency conditions. In addition, the design and operation of the facility must be done to prevent releases. Other requirements include testing and maintenance of equipment and incorporation of communication and alarm systems and contingency plan.	Potentially Relevant & Appropriate	Same as above.	2, 3, 4, 5
33	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 9	The remedial activities may involve treatment within containers and/or storage of treatmc residuals in containers. These containers must be in good condition, compatible with the waste, kept closed except to add or remove materials and be inspected weekly. The area used to store the containers must provide adequate secondary containment and be designed with runoff controls. Also, appropriate closure of the containers must take place.	Potentially Relevant & Appropriate	The requirements may be applicable if CERCLA response action constitut treatment, storage, or disposal as defined under RCRA, or may be relevant and appropriate if the requirements address problems or situations sufficiently similar to the specific circumstances at the site that their usage will be well suited. Site 13 Cluster is not a TSD facility.	2, 3, 4, 5
34	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 10	The remedial activities may involve storage and/or treatment in tanks. These tanks are required to have secondary containment, be monitored and inspected, be provided with overfill and spill protection controls, and operated with adequate freeboard. Also, appropriate closure must take place.	Potentially Relevant & Appropriate	Same as above.	2, 3, 4, 5
35	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 12	The waste piles should be placed upon a lined foundation or base with a leachate system, protected from precipitation and wind dispersal, designed to prevent run on and run off. Also, closure and post-closure care requirements.	Potentially Relevant & Appropriate	Remedial action may involve soil excavation and the compiling of soil in a temporary waste pile for the injection barrier.	3, 4, 5
36	HWCA	Title 22, CCR, Div 4.5, Ch 14, Article 16	Applies to waste management unit not otherwise regulated under RCRA. It may include pumps, auxiliary equipment, air strippers, etc. The substantive requirements include design, construction, operation, maintenance and closure of the unit that will ensure protection of human health and the environment. The actions include general inspections for safety and operation efficiency, testing and maintenance of the equipment (including testing of warning systems).	Potentially Relevant & Appropriate	Remedial activities may involve the use of pumps, auxiliary equipment, air strippers, piping, etc. for Site 13 In-Situ Bioremediation, In-Situ Oxidation, and Ex-Situ Groundwater treatment. Double wall piping and leak detection will be required if the waste meets the RCRA hazardous waste criteria.	3, 4, 5

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
37	HWCA	Title 22, CCR, Div 4.5, Ch 18, Article 1, 3, 4, 10, 11	Movement of hazardous waste to new locations and placed in or on land will trigger LDR. General applicability, dilution prohibited, waste analysis and record keeping, and special rules apply for wastes that exhibit a characteristic waste. Best Demonstrated Available Technology (BDA) standards for each hazardous constituents in each listed waste, if residual is to be disposed. Treatment standards table when necessary.	Applicable	Where applicable, hazardous waste generated from remedial activities must comply with LDR and meet or notify the disposal facility of the treatment standards before disposal at an appropriate offsite disposal facility.	2, 3, 4, 5
38	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.111, §66264.112, §66264.115 through 120	Owners and operators shall close a facility and perform post-closure care when contaminated subsurface soil cannot be practically removed or decontaminated.	Relevant and Appropriate	Contaminated soil, residues, or groundwater from remedial action at a site will achieve clean closure, otherwise, post-closure care requirements will be relevant and appropriate.	3, 4, 5
39	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.91 (a) and (c)	Owners or operators of a RCRA surface impoundment, waste pile, land treatment unit, or landfill shall conduct a monitoring and response program for each regulated unit.	Potentially Relevant & Appropriate	Substantive technical requirements are potentially relevant and appropriate for remedial action including groundwater monitoring.	2, 3, 4, 5
40	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.97 (b), (c), (d) and (e)(1) through (e)(5)	Requirements for monitoring groundwater, surface water, and vadose zone.	Potentially Relevant & Appropriate	Same as above	2, 3, 4, 5
41	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.193 (b) and (c)	In order to prevent release of hazardous constituents to the environment, tank systems, including ancillary equipment, shall have secondary containment (e.g., double-wall piping).	Potentially Relevant & Appropriate	Applicable to conventional remedial systems.	3, 4, 5
42	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.98	Requires the owner or operator of a regulated unit to develop a detection monitoring program that will provide reliable indication of a releas	Potentially Relevant & Appropriate	Same as above	3, 4, 5
43	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.99	Requires the owner or operator of a regulated unit to develop an evaluation monitoring program that can be used to assess the nature and extent of a release from the unit.	Potentially Relevant & Appropriate	Same as above	3, 4, 5
44	HWCA	Title 22, CCR, Div 4.5, Ch 14, §66264.100 (a) through (d), (f), (g)(1), and (h)	The owner or operator is required to take corrective action under Title 22, CCR, §66264.9 to remediate releases from the regulated unit and to ensure that the regulated unit achieves compliance with the water quality protection standard.	Relevant and Appropriate	Same as above	3, 4, 5
45	Safe Water Drinking Act (SFDA), Underground Injectic Control (UIC) Regulations Toxic Injection Well Control Act of 1985	40 CFR, §260.10 Parts 144 through 147 Cal. Health and Safety Code, §25159.10 through 25	Establishes minimum requirements for UIC programs such as permits for the injection wells. Injection may not cause a violation of the primary MCLs and requires the evaluati of the quality of water.	Applicable	Potentially applicable for alternative utilizing a groundwater injection opti to aquifers that are or may reasonable be expected to be a source of drinkin water. If the treated water is most likely to be at or below the applicable primary MCLs, it is highly unlikely to be classified as either a RCRA or no RCRA hazardous waste. Consequently, the reinjection wells would be Cla V wells under SDWA UIC regulations. The substantive requirements of UIC regulations for Class V wells need to be met.	3, 4, 5
46	California Health and Safety Code California Civil Code	Cal. Health and Safety Code, §25202.5, 25222.1 Cal. Civil Code, §1471	Allows DTSC to enter into an agreement with the owner of a hazardous waste facility to restrict present and future land usages. Provides a streamlined process to be used for entering into an agreement to restrict specific usage of property in order to implement land-use restrictions	Relevant and Appropriate	The substantive provisions of Cal. Health and Safety Code (HSC), §25202. are the general narrative standards to restrict "[p]resent and future uses of a or part of the land on which the … facility … is located …" HSC §25222.1 provides the authority for the state to enter into voluntary agreement to establish land-use covenants with the owner of the property. The substantive provision of this section is the general narrative standard "[restricting specified uses of the property]". Cal. Civil Code §1471 provides conditions under which land-use restrictio will apply to successive owners of land.	1, 2, 3, 4, 5
47	Occupational Health and Safety Act	Cal. Health and Safety Code, Div 5, §6300 et seq.	Specific requirements that employers must meet to ensure the safety of the employees	Relevant and Appropriate	The provisions of this act should be followed for the removal action. A health and safety plan has been developed for the proposed removal action and is contained in the IRA Work Plan.	2, 3, 4, 5

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
48	CCR	Title 22, CCR, §66264	Container storage requirements and storage time limitations	Applicable	Applicability of this requirement is contingent upon generation and management of hazardous waste.	2, 3, 4, 5
49	U.S. Department of Transportation	49 CFR, 171-172	Regulates storage, packaging, labeling, and placarding requirements for hazardous materials with regards to transportation.	Applicable	Portions of these requirements would be ARARs for transport of material (site. Off-site transport must comply with both substantive and administrative requirements.	2, 3, 4, 5
50	State Hazardous Waste Regulations Discharges of Waste to Land	Title 23, CCR, §2510-§2600	Regulates waste discharges to land that may affect water quality. Includes siting, design, construction, operation, closure and monitoring standards and criteria for establishing cleanup levels.	Applicable	Substantive requirements of these regulations are applicable at Site 13C.	2, 3, 4, 5
51	Hazardous Waste Control Act as implemented by Standards for Generators of Hazardous Waste	Health and Safety Code, Sec. 25100 et seq., Title 26, CCR, Div. 22, §66262	Establishes state hazardous program in lieu of federal RCRA. Establishes standards for generators and transporters of hazardous wastes in California. Authorization for state program was obtained from U.S. EPA in 1992. Establishes recordkeeping, reporting and manifesting standards for hazardous waste generators in California. Establishes storage accumulation time, requires hazardous waste determination, specifies labeling, container segregation of incompatible wastes, and secondary containment requirement.	Applicable	CERCLA sites are exempt from these administrative requirements. Substantive requirements will apply for any offsite transportation of wastes from Site 13C.	2, 3, 4, 5
52	Hazardous Waste Control Act as implemented by Lan Disposal Restrictions	Title 22, CCR, Div. 4.5, §66268	Identifies wastes and chemical concentration levels that are restricted from land disposal.	Applicable	Will be applicable for drill cuttings or treatment residuals with chemical concentrations exceeding regulatory levels.	3, 4, 5
53	Hazardous Waste Control Act as implemented by Corrective Action Management Units (CAMU)	Title 22, CCR, Div. 4.5, §66264.552	Establishes location and operating requirements for Corrective Action Management Units used in remedial actions.	Applicable	Applicable for treatment units for excavated soil (e.g., drill cuttings), landfilled material, or extracted water. Applies to both RCRA and non-RCRA wastes.	3
54	Hazardous Waste Control Act as implemented by Temporary Units	Title 22, CCR, Div. 4.5, §66264.553	Allows Department of Toxic Substances Control (DTSC) to approve design, operation an closure standards for temporary units used for treatment or storage of wastes generated during remedial actions. DTSC may require alternative standards more protective of human health and the environment.	Relevant & Appropriate	Relevant and appropriate for remedial alternatives that include the use of temporary on-site treatment units.	5
55	Hazardous Waste Control Act as implemented by Miscellaneous Units	Title 22, CCR, Div.4.5, §66264.600-§66264.603	Establishes standards for environmental performance, monitoring, inspections and post-closure care for miscellaneous units used in waste treatment, storage, or disposal.	Applicable	Substantive portions will be applicable for remedial alternatives.	3
56	Water Well Standards	Dept. of Water Resources Bulletin 74-81 and 74-90	Sets requirements for the construction and abandonment of water extraction and injection wells throughout the state.	Applicable	Will apply for any monitoring, injection, or extraction wells constructed or abandoned during remedial actions.	2, 3, 4, 5
57	Waste Discharge Requirements	Water Code Sec. 13260 et seq. (Porter-Cologne Water Quality Control Act)	Requires filing of a "Report of Waste Discharge" with the RWQCB for any proposed discharges affecting "the waters of the state."	Potentially Applicable	Under CERCLA, on-site actions are exempt from reporting requirements. However, the reporting requirement must be met for any offsite discharges.	N/A
58	Policies and Procedures for Investigation and Cleanup and Abatement and Closure	California Water Code 13304 as implemented by State Water Resources Control Board Resolution No. 92-49	Establishes policies and procedures for oversight of investigations, cleanups and abateme activities resulting from discharges which affect or threaten water quality.	Applicable	Applicable for all cleanup and abatement activities which may cause or permit discharges to waters of the state and create or threaten to create a condition of pollution or nuisance in violation of any waste discharge requirement.	3
59	Hazardous Materials Release Response Plans and Inventory	Health and Safety Code, Div. 20, Chapter 6.95	Establishes requirements for emergency response plans for a release or threatened release of hazardous materials. Reporting requirements are established.	Applicable	Substantiative requirements will be applicable to sites with remedial actions where hazardous materials may be handled.	3, 4, 5
60	Staff Report of the RWQCB, CVR	"A Compilation of Water Quality Goals"	Provides guidance on selecting numerical values to implement narrative water quality objectives contained in the Basin Plan.	To Be Considered	Performance Standard. To be considered in selecting appropriate numerical values to implement the Basin Plan for setting cleanup levels and discharge limits. The numerical values contained in the staff report may be ARAR's, or Performance Standards, depending on the source of the values.	3, 4, 5

#	Source	Standard, Requirement, Criterion, Limitation	Description of Standard	ARARs or To Be Considered	Comments	Alternative(s) Considered
Action-Specific ARARs						
61	Porter-Cologne Water Quality Control Act (California Water Code Sections13000, 13140, 13240, 13260, 13263, 13267, 13300, 13304, 13307)	State Water Resources Control Board Resolution No. 92-49 (As amended April 21, 1994)	Establishes requirements for investigation and cleanup and abatement of discharges. Among other requirements, dischargers must clean up and abate the effects of discharges a manner that promotes the attainment of either background water quality, or the best wat quality that is reasonable if background water quality cannot be restored. Requires the application of Title 23, CCR, Section 2550.4, requirements to cleanups.	Applicable	Applies to groundwater remedial actions.	3, 4, 5
62	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20090(d), Title 23, CCR, §2511 (d)	Action taken by public agencies to clean up unauthorized releases are exempt from Title 27/ Title 23 accept that wastes removed from immediate place of release and discharged to land must be managed in accordance with classification (Title 27, CCR, Section 20200/ Title 23, CCR, Section 2520) and siting requirements of Title 27 or Title 23 and wastes contained or left in place must comply with Title 27 or Title 23 to the extent feasible.	Applicable	Applies to remediation and monitoring of sites.	2, 3, 4, 5
63	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20410, Title 23, CCR, §2550.6	Requires monitoring for compliance with remedial action objectives for three years from the date of achieving cleanup standards.	Applicable	Applies to groundwater remedial actions.	3, 4, 5
64	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20415, Title 23, CCR, §2550.7.	Requires general soil, surface water, and ground water monitoring.	Applicable	Applies to all areas at which waste has been discharged to land.	2, 3, 4, 5
65	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title, 27, CCR, §20425, Title, 23, CCR, §2550.9.	Requires an assessment of the nature and extent of the release, including a determination the spatial distribution and concentration of each constituent.	Applicable	Applies to areas at which monitoring results show statistically significant evidence of a release.	2, 3, 4, 5
66	Porter-Cologne Water Quality Control Act (California Water Code Sections 13140-13147, 13172, 13260, 13263, 13267, 13304).	Title 27, CCR, §20430, Title 23, CCR §2550.10	Requires implementation of corrective action measures that ensure that cleanup levels are achieved throughout the zone affected by the release by removing the waste constituents or treating them in place. Source control may be required. Also requires monitoring to determine the effectiveness of the corrective actions.	Applicable	Applies to groundwater remedial actions.	3, 4, 5

TO BE CONSIDERED STATE ADVISORIES, GUIDANCE, AND CRITERIA, CAL/EPA, DTSC

1 *Institutional Control Protocol at Open Bases*
California Military Environmental Coordination Committee (CMECC)
Site Cleanup Performance Action Team

Attachment 1

Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
AMPHIBIANS						
Ambystoma californiense	California tiger salamander	FT, CSC		E		E
Taricha torosa	California newt	CSC		E	E	E
Ensatina eschscholtzi croceator	Yellow-blotched salamander	CSC		O	O	
Aneides lugubris	Arboreal salamander			E	O	
Batrachoseps attenuatus	California slender salamander			O	E	
Batrachoseps nigriventris	Black-bellied slender salamander				E	
Scaphiopus hammondi	Western spadefoot	CSC		E		
Bufo boreas	Western toad			E	E	E
Bufo microscaphus	Southwestern toad					E
Hyla cadaverina	California treefrog			E	E	E
Hyla regilla	Pacific treefrog			O	O	O
Rana aurora draytonii	California red-legged frog	FT, CSC		O		O
Rana catesbeiana	Bullfrog		HA	E	E	O
REPTILES						
Clemmys marmorata pallida	Southwestern pond turtle	CSC		E		O
Sceloporus occidentalis	Western fence lizard			O	O	
Uta stansburiana	Side-blotched lizard			E	E	
Phrynosoma coronatum frontale	California coast horned lizard	CSC		E	O	
Eumeces skiltonianus	Western skink			O	O	
Cnemidophorus tigris	Western whiptail			E	E	
Gerrhonotus multicarinatus	Southern alligator lizard			O	O	
Anniella pulchra pulchra	Silvery legless lizard	CSC		E	O	
Diadophis punctatus	Ringneck snake			E	E	
Coluber constrictor	Racer			O	O	O
Masticophis flagellum	Coachwhip			E	E	

Attachment 1

Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Masticophis lateralis	California whipsnake			E	O	
Pituophis melanoleucus	Gopher snake				E	
Lampropeltis getulus	Common kingsnake			E	O	E
Lampropeltis zonata	California mountain kingsnake			E		
Thamnophis sirtalis ssp.	South coast garter snake			E	E	E
Thamnophis elegans	Western terrestrial garter snake			O	O	E
Thamnophis hammondii	Two-striped garter snake	CSC		E		E
Tantilla planiceps	Western black-headed snake				E	
Hypsiglena torquata	Night snake			E	E	
Crotalus viridis	Western rattlesnake			O	O	E
BIRDS						
Podilymbus podiceps	Pied-billed grebe					O
Podiceps caspicus	Eared grebe					O
Aechmorphorus occidentalis	Western grebe					O
Aechmorphorus clarkii	Clark'e grebe					E
Phalacrocorax auritus	Double-crested cormorant	CSC				O
Aix sponsa	Wood duck		HA	E		O
Anas platyrhynchos	Mallard		HA	E		O
Anas crecca	Green-winged teal		HA	E		O
Anas acuta	Northern pintail		HA			O

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Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Anas discors	Blue-winged teal		HA			O
Anas cyanoptera	Cinnamon teal		HA			O
Anas clypeata	Northern shoveler		HA			O
Anas strepera	Gadwall		HA			O
Anas americana	American wigeon		HA			E
Anas penelope	Eurasian wigeon					E
Aythya valisineria	Canvasback		HA			E
Aythya americana	Redhead		HA			E
Aythya collaris	Ring-necked duck		HA			O
Aythya marila	Greater scaup		HA			O
Aythya affinis	Lesser scaup		HA			E
Bucephala albeola	Bufflehead		HA			E
Lophodytes cucullatus	Hooded merganser		HA			
Mergus merganser	Common merganser		HA	E		E
Mergus serrator	Red-breasted merganser		HA			E
Oxyura jamaicensis	Ruddy duck		HA			O
Fulica americana	American coot		HA	O		O
Larus delawarensis	Ring-billed gull					O
Larus californicus	California gull	CSC				E
Larus argentatus	Herring gull					E
Larus philadelphia	Bonaparte's gull					E
Larus glaucescens	Glaucus-winged gull					E
Sterna caspia	Caspian tern					O
Sterna hirundo	Common tern					O
Sterna forsteri	Forster's tern					O
Ardea herodias	Great blue heron			O		O
Casmerodius albus	Great egret			O		O
Egretta thula	Snowy egret			O		O

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Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Bubulcus ibis	Cattle egret			E		E
Butorides striatus	Green-backed heron			E		E
Nycticorax nycticorax	Black-crowned night heron			E		E
Plegadis chihi	White-faced ibis	CSC				E
Cygnus columbianus	Tundra swan					E
Anser albifrons	Greater white-fronted goose		HA			O
Chen caerulescens	Snow goose		HA			E
Branta bernicla	Brant		HA			E
Branta canadensis	Canada goose		HA			O
Ixobrychus exilis hesperis	Western least bittern	CSC		O		O
Botaurus lentiginosus	American bittern			O		E
Porzana carolina	Sora					E
Rallus limicola	Virginia rail			O		E
Gallinula chloropus	Common moorhen		HA			E
Himantopus mexicanus	Black-necked stilt					E
Recurvirostra americana	American avocet					E
Pluvialis squatarola	Black-bellied plover					O
Charadrius semipalmatus	Semipalmated plover					E
Charadrius alexandrinus nivosus	Western snowy plover	FT, CSC				E
Charadrius vociferus	Killdeer			O		O
Limosa fedoa	Marbled godwit					O
Niumenius americanus	Long-billed curlew	CSC				E
Niumenius phaeopus	Whimbrel					E
Catoptrophorus semipalmatus	Willet					O
Tringa melanoleuca	Greater yellowlegs					O
Tringa flavipes	Lesser yellowlegs					E
Tringa solitaria	Solitary sandpiper			E		O
Gallinago gallinago	Common snipe		HA			E

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Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Phalaropus tricolor	Wilson's phalarope					O
Lobipes lobatus	Northern phalarope					O
Limnodromus griseus	Short-billed dowitcher					E
Limnodromus scolopaceus	Long-billed dowitcher					O
Actitis macularia	Spotted sandpiper					O
Calidris minutilla	Least sandpiper					O
Calidris mauri	Western sandpiper					O
Erolia bairdii	Baird's sandpiper					O
Erolia melanotos	Pectoral sandpiper					O
Calidris alpina	Dunlin					E
Callipepla californica	California quail		HA	O	O	
Pandion haliaetus	Osprey	CSC		O		O
Elanus caeruleus	Black-shouldered kite			O	O	E
Haliaeetus leucocephalus	Bald eagle	FT (FPD), SE		E		
Circus cyaneus	Northern harrier	CSC		O	O	O
Accipiter striatus	Sharp-shinned hawk	CSC		O	E	
Accipiter cooperii	Cooper's hawk	CSC		O	O	
Buteo jamaicensis	Red-tailed hawk			O	O	E
Buteo lineatus	Red-shouldered hawk			O	O	E
Buteo regalis	Ferruginous hawk	CSC		E	E	
Buteo lagopus	Rough-legged hawk			E	E	E
Aquiala chrysaetos	Golden eagle	CSC		E	E	
Cathartes aura	Turkey vulture			O	O	O
Falco sparverius	American kestrel			O	O	E
Falco columbarius	Merlin	CSC		E	O	E
Falco peregrinus anatum	Peregrine falcon	SE		E	O	E
Falco mexicanus	Prairie falcon	CSC			E	E
Tyto alba	Barn owl			O	O	E
Otus kennicottii	Western screech owl			E	E	
Bubo virginianus	Great horned owl			O	O	E
Athene cunicularia hypugea	Burrowing owl	CSC			O	

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Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Asio otus	Long-eared owl	CSC		O	E	
Asio flammeus	Short-eared owl	CSC			E	E
Chordeiles acutipennis	Lesser nighthawk			E		E
Phaelaenoptilus nuttallii	Common poorwill				E	E
Chaetura Vauxi	Vaux's swift	CSC		E		
Aeronautes saxatalis	White-throated swift			E	E	E
Ceryle alcyon	Belted kingfisher			O		O
Zenaida macroura	Mourning dove		HA	O	O	
Columba fasciata	Band-tailed pigeon		HA	O		
Columba livia	Rock dove				O	
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	SE		E		
Geococcyx californianus	Greater roadrunner				O	
Calypte anna	Anna's hummingbird			O	O	
Calypte costa	Costa's hummingbird			E	E	
Stellula calliope	Calliope hummingbird			E	E	
Selasphorus rufus	Rufous hummingbird			E		
Selasphorus sasin	Allen's hummingbird			O	E	
Melanerpes formicivorus	Acorn woodpecker			E		
Sphyrapicus ruber	Red-breasted sapsucker			E		
Picoides pubescens	Downy woodpecker			O	E	
Picoides villosus	Hairy woodpecker			O		
Colaptes auratus	Northern flicker			O	O	
Picoides nuttallii	Nuttall's woodpecker			O		
Sayornis nigricans	Black phoebe			O		O
Sayornis saya	Say's phoebe				O	
Contopus sordidulus	Western wood pewee			O		
Empidonax traillii extimus	Southwestern willow flycatcher	FE		O		
Empidonax difficilis	Pacific slope flycatcher			O		
Myiarchus cinerascens	Ash-throated flycatcher			O		

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Species Potentially Present in Terrestrial Habitats at Site 13 Cluster, Vandenberg Air Force Base

SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Tyrannus vociferans	Cassin's kingbird			O	E	
Tyrannus verticalis	Western kingbird			O	O	O
Eremophila alpestris actia	California horned lark	CSC			O	
Anthus rubescens	American pipit					E
Progne subis	Purple martin	CSC		E		E
Tachycineta bicolor	Tree swallow			O		O
Tachycineta thalassina	Violet-green swallow			O	E	O
Stelgidopteryx serripennis	Northern rough-winged swallow			O	E	E
Riparia riparia	Bank swallow	ST		O		
Hirundo pyrrhonota	Cliff swallow			O	O	O
Hirundo rustica	Barn swallow			E	E	E
Corvus brachyrhynchos	American crow		HA	O	O	O
Aphelocoma coerulescens	Scrub jay			O	O	O
Pica nuttalli	Yellow-billed magpie			E		
Parus rufescens	Chestnut-backed chickadee			O		
Parus inornatus	Plain titmouse			E		
Psaltriparus minimus	Bushtit			O	O	
Sitta canadensis	Red-breasted nuthatch			E		
Certhia americana	Brown creeper			E		
Troglodytes aedon	House wren			O	E	
Troglodytes troglodytes	Winter wren			E		
Thryomanes bewickii	Bewick's wren			O	O	
Cistothotrus palustris	Marsh wren			O		O
Chamaea fasciata	Wrentit			O	O	
Regulus calendula	Ruby-crowned kinglet			O	O	
Polioptila caerulea	Blue-gray gnatcatcher			O	O	
Mimus polyglottos	Northern mockingbird			E	O	
Oreoscoptes montanus	Sage thrasher				E	
Toxostoma redivivum	California thrasher			O	O	
Catharus ustulatus	Swainson's thrush			O	E	
Catharus guttatus	Hermit thrush			O	E	

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SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Turdus migratorius	American robin			O		
Ixoreus naevius	Varied thrush			E		
Sialia mexicana	Western bluebird			O	O	
Bombycilla cedrorum	Cedar waxwing			E		
Phainoplepla nitens	Phainopepla			E		
Lanius ludovicianus	Loggerhead shrike	CSC		O	O	
Sturnus vulgaris	European starling			O	O	O
Vireo solitarius	Solitary vireo			E		
Vireo huttoni	Hutton's vireo			O		
Vireo gilvus	Warbling vireo			O		
Vermivora celata	Orange-crowned warbler			O	O	
Vermivora ruficapilla	Nashville warbler			O		
Parula americana	Northern parula			O		
Dendroicia coronata	Yellow-rumped warbler			O	E	O
Dendroicia nigrescens	Black-throated gray warbler			O		
Dendroicia petechia	Yellow warbler	CSC		O	E	
Dendroica townsendi	Townsend's warbler			E		
Dendroica occidentalis	Hermit warbler			O		
Dendroica palmarum	Palm warbler			O		
Mniotilta varia	Black-and-white warbler			O		
Oporornis tolmiei	MacGillvray's warbler			E		
Geothlypis trichas	Common yellowthroat			O		O
Wilsonia pusilla	Wilson's warbler			O	E	
Icteria virens	Yellow-breasted chat	CSC		O		
Piranga ludoviciana	Western tanager			E		
Pheucticus ludovicianus	Rose-breasted grosbeak			O		
Pheucticus melanocephalus	Black-headed grosbeak			O		
Guiraca caerulea	Blue grosbeak			O		
Passerine amoena	Lazuli bunting			O	E	
Euphagus cyanocephalus	Brewer's blackbird			O	O	O
Agelaius tricolor	Tricolored blackbird	CSC		E		O

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SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat		
				VFR	CSS	FEA
Agelaius phoeniceus	Red-winged blackbird			O		O
Xanthocephalus xanthocephalus	Yellow-headed blackbird					E
Icterus cucullatus	Hooded oriole			E		
Icterus galbula	Northern oriole			E		
Sturnella neglecta	Western meadowlark				O	
Molothrus ater	Brown-headed cowbird			E	E	E
Zonotrichia leucophrys	White-crowned sparrow			O	O	E
Zonotrichia atricapilla	Golden-crowned sparrow			E	O	
Chondestes grammacus	Lark sparrow			E	E	
Amphispiza belli belli	Bell's sage sparrow	CSC			O	
Aimophila ruficeps canescens	Southern California rufous-crowned sparrow	CSC			O	
Spizella passerina	Chipping sparrow					
Spizella atrogularis	Black-chinned sparrow			O	E	
Pooecetes gramineus	Vesper sparrow				E	
Passerella iliaca	Fox sparrow			E	E	
Melospiza melodia	Song sparrow			O	O	O
Melospiza lincolnii	Lincoln's sparrow			E	E	E
Melospiza georgiana	Swamp sparrow			O		O
Pipilo erythrophthalmus	Rufous-sided towhee			E	O	
Pipilo crissalis	California towhee			O	O	
Junco hyemalis	Dark-eyed junco			O	E	
Carpodacus mexicanus	House finch			O	O	
Carduelis tristis	American goldfinch			O	E	
Carduelis lawrencei	Lawrence's goldfinch			E		
Carduelis psaltria	Lesser goldfinch			O	E	O
Carpodacus purpureus	Purple finch			O	O	
Pheucticus melanocephalus	Black-headed grosbeak			O	O	
MAMMALS						
Didelphis virginiana	Virginia opossum		HA	O	E	O

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SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat		
				VFR	CSS	FEA
Sorex trowbridgii	Trowbridge shrew			O	O	
Sorex ornatus	Ornate shrew			O	O	E
Scapanus latimanus	Broad-footed mole			E	O	
Myotis yumanensis	Yuma myotis			E	E	E
Myotis evotis	Long-eared myotis			E	E	E
Myotis thysanodes	Fringed myotis			E	E	E
Myotis volans	Long-legged myotis			E	E	E
Myotis californicus	California myotis			E	E	E
Myotis leibii	Small-footed myotis			E	E	E
Lasionycteris noctivagans	Silver-haired bat			E	E	
Pipistrellus hesperus	Western pipistrelle			E	E	E
Eptesicus fuscus	Big brown bat			E	E	E
Lasiurus borealis	Red bat			E	E	E
Lasiurus cinereus	Hoary bat			E	E	E
Plecotus townsendii townsendii	Townsend's western big-eared bat	CSC		E	E	E
Antrozous pallidus	Pallid bat	CSC		E	E	E
Tadarida brasiliensis	Brazilian free-tailed bat			E	E	E
Eumops perotis californicus	California mastiff bat	CSC		E	E	E
Lepus californicus	Black-tailed jackrabbit		HA	E	O	
Sylvilagus audubonii	Desert cottontail		HA	O	O	O
Sylvilagus bachmanii	Brush rabbit		HA	O	O	
Castor canadensis	Beaver			O		
Tamias merriamii	Merriam's chipmunk			E		
Spermophilus beecheyi	California ground squirrel			O	O	O
Sciurus griseus	Western gray squirrel		HA	E		
Thomomys bottae	Valley pocket gopher			O	O	
Perognathus californicus	California pocket mouse			O	O	O
Dipodomys heermanni	Heermann's kangaroo rat				O	
Dipodomys agilis	Pacific kangaroo rat			O	O	O
Reithrodontomys megalotis	Western harvest mouse			O	O	E
Peromyscus californicus	California mouse			O	O	O

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SCIENTIFIC NAME	COMMON NAME	Regulatory Status	Recreational Status	Occurrence by Habitat VFR	CSS	FEA
Peromyscus maniculatus	Deer mouse			O	O	O
Peromyscus boylii	Brush mouse			E	E	
Peromyscus truei	Piñon mouse			E	E	
Onychomys torridus	Southern grasshopper mouse			E	E	E
Neotoma lepida intermedia	San Diego desert wood rat	CSC			O	
Neotoma fuscipes	Dusky-footed woodrat			O	O	O
Microtus californicus	California vole			O	O	O
Ondatra zibethicus	Muskrat		HA	E		E
Rattus rattus	Black rat			E		
Mus musculus	House mouse			E		E
Procyon lotor	Raccoon			O	O	O
Mustela frenata	Long-tailed weasel			O	O	E
Taxidea taxus	American badger				O	
Spilogale gracilis	Western spotted skunk		HA	E	E	E
Mephitis mephitis	Striped skunk		HA	O	E	E
Canis latrans	Coyote			O	O	O
Urocyon cinereoargenteus	Gray fox			E	O	E
Ursus americanus	Black bear			E	E	
Felis concolor	Mountain lion			E	E	
Lynx rufus	Bobcat			O	O	E
Sus scrofa	Feral hog		HA	O	O	O
Odocoileus hemionus	Mule deer		HA	O	O	